AD 741615

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

IN REPLY REFER TO
DAEN-MER-D

20 April 1972

SUBJECT: Review of Distribution Statement on Technical Document

Director
U.S. Army Engineer Waterways
Experiment Station
ATTN: WESTR

1. Reference your letter, 28 March 1972, subject as above.

2. The Miscellaneous Paper Number 4-966, "Tests of Expedient Ramps to Carry Over-the-Beach Traffic" has been reviewed and the present restriction can be cancelled and Statement A imposed.

FOR THE CHIEF OF ENGINEERS:

PAUL F. CARLTON
Acting Chief
Resource Development Division
Directorate of Military Engineering

Details of illustrations in
this document may be better
studied on microfiche

AD 741 615

Misc Paper 4-966

MISCELLANEOUS PAPER NO. 4-966

TESTS OF EXPEDIENT RAMPS TO CARRY OVER-THE-BEACH TRAFFIC

by

V. C. Barber

February 1968

Sponsored by

Office, Chief of Engineers
U. S. Army

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

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TESTS OF EXPEDIENT RAMPS TO CARRY OVER-THE-BEACH TRAFFIC

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ARMY-MRC VICKSBURG MISS

FOREWORD

The investigation reported herein was sponsored by the Office, Chief of Engineers, and was conducted under Project 17, Operations and Maintenance, Army, "Development of Design Criteria for Construction of Expedient Ramps to Carry Over-the-Beach Traffic." The tests were conducted to study the feasibility of using existing expedient surfacing materials in construction of ramps to carry over-the-beach (OTB) traffic off-loading materiel from miscellaneous beach landing craft.

The engineer tests were conducted at the U. S. Army Engineer Waterways Experiment Station (WES) during the period from April through July 1967. The U. S. Naval Seabee Battalion Training Center, Gulfport, Mississippi, and elements of the U. S. Army Engineer Command, Vietnam, APO San Francisco 96307, provided information to supplement the test data obtained.

Engineers of the WES Soils Division who were actively engaged in planning, testing, and report phases of this study were Messrs. R. G. Ahlvin and C. D. Burns and CPT V. C. Barber. The work was performed under the general supervision of Messrs. W. J. Turnbull and A. A. Maxwell, Chief and Assistant Chief, respectively, of the Soils Division. This report was prepared by CPT Barber.

COL John R. Oswalt, Jr., CE, was Director of WES during the conduct of this investigation and the publication of this report. Mr. J. B. Tiffany was Technical Director.

Acknowledgment is made to personnel of the WES Hydraulics Division for their assistance and cooperation in this investigation.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
tons	907.185	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
pounds per cubic foot	16.0185	kilograms per cubic meter

SUMMARY

Engineer tests were conducted on a full-scale model beach in a wave tank of the WES Hydraulics Division. The beach was constructed of sand approximating that found on beaches in the SE Asian theater of operations (TO). Beach slopes ranged from 10 to 20 percent. Waves induced upon the beach simulated those found in TO cove and bay areas.

The tests were conducted by installing various types of expedient surfacing materials such as M6 pierced steel plank landing mat and XM19 aluminum landing mat with and without anchors and with and without T16 membrane over a prepared sand beach and subjecting these installations to wave action and vehicular traffic.

The separate ramps were tested by first observing detrimental effects caused by wave action alone and then by a combination of wave action and traffic loading. These same factors were observed in determining detrimental effects of traffic and waves on a bare beach. Standard military vehicles used in the trafficking cycles were the M151 1/4-ton cargo truck and the M35 2-1/2-ton 6x6 cargo truck.

None of the materials or combinations thereof satisfactorily stabilized the beach foreshore or provided an OTB ramp appreciably better than the natural, bare sand. Benefits gained by installation of any of these OTB ramps are short term due to the rapid deterioration of the ramp foundation.

TESTS OF EXPEDIENT RAMPS TO CARRY OVER-THE-BEACH TRAFFIC

PART I: INTRODUCTION

Background

1. Present concepts in the theater of operations (TO) include delivery of Army materiel over natural beaches where permanent harbor facilities have not been constructed. Current tactics and logistical commitments require that these unloading operations be executed as hastily and with as few complications as possible. Difficulties have been encountered in the rapid unloading of waterborne cargo by use of wheeled cargo vehicles presently in the Army Table of Organization and Equipment. In previous unloading operations, pierced steel landing mat (M8) has been used for the construction of expedient over-the-beach (OTB) ramps that extended to a point near the water's edge at low tide. This mat has provided a satisfactory ramp over the dry sand or backshore area of the beaches. However, problems have developed in the foreshore areas due to loss of sand from under the mat caused by wave and traffic action, resulting in the immobilization of wheeled cargo vehicles during the unloading operations. Further knowledge was therefore required as to methods and materials that would be more suitable in the construction of expedient OTB ramps.

Previous Investigations

2. Field tests were conducted in May-June 1959 at La Turballe Beach and Suscinio Beach, on the Brittany coast of France, on three metal landing mats and three prefabricated membranes to determine their suitability and effectiveness as portable surfacing expedients for increasing the trafficability potential of unprepared beaches for emergency offshore discharge operations.* Landing mats tested were PSP, M8, and T11. Membranes tested were T1 vinyl-coated cotton duck membrane, and T12 and T14 neoprene-coated

* S. G. Tucker and J. L. Garrett, "Beach Stabilization Tests of Landing Mats and Prefabricated Membranes," Technical Report No. 3-592, Feb 1962, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

nylon membranes. Test results indicated that, although M8 mat was the most desirable of the materials tested, none of the ramps were capable of stabilizing the beach near the water's edge and thus providing a satisfactory ramp. It was recommended that a study be conducted to develop a more satisfactory lightweight surfacing expedient for beach stabilization that would include investigation of the effects of wave action, beach slope, tide, and variations in composition of beach materials.

Purpose and Scope of Tests

3. The purpose of these tests was to (a) develop construction procedures and techniques for using currently available expedient surfacing materials that will ensure satisfactory OTB ramps, and (b) consider the feasibility of other concepts of materials for construction of OTB ramps. It was specifically desired to determine the effects of the following variables on ramp performance:

- a. Slope of the beach.
- b. Expedient surfacing material.
- c. Location of ramp with respect to the water's edge.
- d. Method of anchoring the ramp.
- e. Use of membrane underlay for the ramp.
- f. Traffic loading.
- g. Duration of wave and traffic action.

4. The scope of the test included constructing beaches and testing full-scale OTB ramp models in the L-shaped wave tank of the Hydraulics Division, Waterways Experiment Station (WES). Various OTB ramps were placed on the beach and subjected to vehicle loading and wave action. Three basic wave types were used, which varied in height from 0.5 to 0.9 ft.* As testing proceeded, data were collected and observations were made pertinent to the variables listed above. Due to the nature of this type of testing, the effects of these variables were documented largely by photographs. In addition, other statements as to effects of variables are the result of engineer observation made with the aid of cross sections, straight-line

* A table of factors for converting British units of measurement to metric units is presented on page vii.

deviation measurements, and opinions of engineers of the WES Hydraulics Division.

Definitions of Pertinent Terms

5. For clarity, the meanings of certain terms used in this report are defined below.

- a. Beach.* The zone of unconsolidated material that extends landward from the low-water line to the place where there is marked change in material or physiographic form (usually the effective limit of storm waves). A beach includes foreshore and backshore.
- b. Foreshore.* That part of the beach that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.
- c. Backshore.* That part of the beach between the foreshore and the dune area or coastline and acted upon by waves only during severe storms.
- d. Dune area. An area of wind-deposited sand extending along the top of the backshore or coastline. Coastal dunes may be active or partially stabilized by vegetation.
- e. Pass. One trip of a test vehicle over the tracking area of the OTB ramp.
- f. Run. A strip equal to one width of the landing mat or membrane.
- g. Erosion. The washing away or removal of soil particles by water moving under and around portions of the landing mat or membrane placed in contact with the soil.
- h. Scour. A place that has been eroded by the act of a water current.
- i. Expedient ramp. A ramp constructed from expedient surfacing materials or other materials and by expedient methods for the purpose of gaining a definite and immediate advantage, and constructed without regard or knowledge of its long-range capability or performance.
- j. Test series. A grouping of tests according to the beach slope.
- k. Test run number. The number assigned to a particular test element, i.e. series 1, test run 1.

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* Extracted from Appendix A of Beach Erosion Board Technical Report No. 4, dated June 1954.

PART II: TEST FACILITY AND EQUIPMENT

Test Facility

6. The tests were conducted in an L-shaped wave tank. The tank, shown in plate 1, is 50 ft wide and is equipped with a wave inducer cap. of creating 1.5-ft-high waves. The wave tank was modified by erecting r. taining walls, approach decks, and approach ramps necessary to contain test the sand beach.

7. A locally available material, called Campbell Swamp sand, was selected for the test beach because it closely resembled sands on beach located in the TO. Comparison of the classification data and gradation curves for the two sands is shown in plate 2 Efforts were made to dupl cate natural beach conditions and the sand was placed in the tank on ap- proximately the desired slope and tamped lightly (photograph 1). The ta was filled with water to a depth of 3 ft and the water was allowed to st for a saturation period. A view of the beach and the filled wave tank i shown in photograph 2. Preliminary waves were induced to consolidate th sand to a natural state. This was verified by density determinations pr. to testing. Dry densities ranged from 97.4 to 102.5 pcf in areas where moisture content was 22 percent.

Wave Characteristics

8. Wave period and height were planned to resemble the waves on T beaches and to determine their respective effects on various ramps. Po elevation of the water in the tank was 3 ft. Wave types and characteris- tics were as follows:

Type	Period second	Height ft	Breaking Height ft
1	5	0.50	0.85
2	4	0.75	1.00
3	3	0.90	1.10

Note: The wave inducer could not generate higher waves of the proper period.

9. The landing mats and membrane tested were selected to represent items currently available in the Army supply system. Auger- and deadman-type anchors as required for testing were either improvised or drawn from existing local stock. The two mats were selected as representative of two available types: the M6 to represent pierced mats, and the XM19 for heavy-duty, solid mats. M6, shown in photograph 3, has been used extensively in the past as an expedient surfacing for light-duty airfields. XM19 mat (photograph 4) is in extensive use in the TO. T16 membrane, a flexible neoprene-coated fabric, was used in conjunction with the landing mat as an underlay in an attempt to control erosion.

Test Vehicles

10. The M151 1/4-ton truck and the M35 2-1/2-ton, 6x6 cargo truck were used to traffic the ramps in order to represent the more typical military cargo vehicles. Normal wheel configurations were used except the outside wheels were removed from the rear tandems of the M35 in order to impose the most severe load condition. Tire pressures were those specified for highway operation, 25 psi for the M151 and 40 psi for the M35.

PART III: TEST RESULTS

11. Phase I included tests on beaches with slopes of 10 and 20 percent. Test runs were conducted on bare beach and ramps of M6 and XM19 mat with various wave types and duration and vehicle loading. Phase II was conducted to evaluate baffling systems for the ramps. Data from these tests are shown in table 1. The tests were interrelated and the results are sometimes discussed concurrently.

Phase I Tests

Slope of the beach

12. In studying the effects of this variable on OTB ramps, it was found that the greater the slope, the greater was the damage sustained by the ramp. The steeper beach slope caused each wave to expend more energy as it broke upon the beach and also allowed a more violent backrush of water from each wave runup. A more thorough study of slope effects was precluded due to the tendency of the wave action to rapidly change the constructed slope to the natural 10 percent slope of the beach in the wave tank. When 20 percent slopes were constructed and waves applied, the beach immediately eroded to a 10 percent slope. Photographs 5 and 6 show a comparison of damages sustained by the ramp on 10 and 20 percent slopes, respectively. As a result of this study, it was concluded that landing-mat ramps cannot adequately control beach erosion on slopes of 10 percent or greater.

Expedient surfacing material

13. M6 and XM19 landing mat were the two expedient surfacing materials tested. In addition, tests were conducted to determine unloading ability over a bare beach. The M6 mat was damaged after 1400 vehicle passes and some beach erosion occurred under and around the mat. The XM19 mat was not damaged by 3500 passes of the 2-1/2-ton cargo truck, but the ramp structure was damaged by scour under the ramp and subsequent deposition of sand on top of the ramp. See photographs 7 and 8 for these conditions. The bare beach proved to be capable of withstanding traffic loading

and wave action without any surfacing materials. As ruts were formed, they were rapidly filled again by wave action. Traffic was halted after 588 passes because it was apparent that the sand beach would sustain indefinite trafficking without appreciable damage (photograph 9). Testing indicated that neither pierced nor solid mat was capable of improving trafficability over a beach foreshore for any appreciable length of time when subjected to wave action. However, these tests showed that in offloading extremely heavy or delicate equipment, XM19 or similar heavy-duty mat could be used on a short-time basis to maintain a smooth, firm traffic area.

Location of ramp with
<u>respect to water's edge</u>

14. Dependent upon the depth of water in the vicinity of the beach, the OTB ramp may be required to extend to a point several feet beyond the water's edge. This could occur when a waterborne cargo carrier could not approach to a point near enough to the water's edge to allow lowering the exit ramp onto the beach and the underwater area near the water's edge was steep enough to require a ramp. Experiences in the TO indicate that when such a ramp is extended any appreciable distance beyond the water's edge, serious damage may be caused to the ramp by the landing of a waterborne vehicle, such as an LST. Tests indicated that when underwater slopes are 10 percent or less, a ramp is not needed because the submerged sand is sufficiently trafficable in most cases. Tests indicated that essentially the same erosion pattern occurred when the ramp was ended 1 ft short of the water's edge or 3 ft beyond the water's edge, as indicated in photographs 10 and 11. These photographs were each taken after two hours of wave action. The erosion patterns are similar, even though the ramp in photograph 10 ended 1 ft short of the water's edge and the end of the ramp in photograph 11 was 3 ft beyond the water's edge. These two ramps were later subjected to traffic loading and the submerged sand proved capable of bearing traffic. Photograph 12 shows an XM19 ramp extended 35 ft beyond the water's edge. The photograph was taken after the tank was drained. This extended ramp enhanced trafficability of the submerged area; however, erosion occurred under the ramp in a fashion similar to that shown in photographs 10 and 11. The extended end of the ramp was buried by eroded sand with

subsequent reduction in the efficiency of the ramp. In summary, it was de-
termined from this test that extension of a ramp beyond the water's edge
unwarranted in most cases.

Method of anchoring the ramp

15. When short, single- or dual-lane OTB ramps are installed with
anchors, excessive ramp movement can occur as a result of traffic acti
Photograph 13 shows a displacement of approximately 37 in. of a 12- by
16-ft XM19 ramp after 422 passes of a 2-1/2-ton cargo truck. The small
ground contact area of the ramp, its smooth bottom surface, and braking
acceleration of the test vehicle caused the movement. This also occurr
in conjunction with pierced mat, though the movement was not as pronou
Mat movement did not affect the performance of the mat or the erosion p
tern; therefore, anchorage is only necessary for the purpose of preventi
excessive movement of the ramp from its original location. In an effort
prevent this movement, two basic types of anchors were used. The auger-
type anchor (photograph 14), which was available in lengths up to 3 ft,
not satisfactory when used in the unstable beach. The toe anchors were
mediately overridden by the ramp when testing began, while the side con-
nectors for the side anchors became disengaged as the mat moved. Photo-
graph 15 shows a disengaged side anchor. When this photograph was taken
the toe anchors had disengaged and were overridden by movement of the ra
The test facility did not permit conventional installation of deadmen
the backshore as anchors. Instead, cables were used to anchor the ramp
the beach retaining wall as a simulation of deadman anchoring. Photogr
16 shows the simulated deadman-type anchor which completely prevented
ment of the ramp. Test results indicated that when anchorage is neces
deadmen and cables should be used in preference to driven pins or auger-
type anchors.

Use of membrane underlay for the ramp

16. Due to the rapid erosion of the sand subgrade under an OTB r
an attempt was made to stabilize the sand by covering the ramp area an
adjacent areas with a protective membrane. T16 membrane was used bec
of its resemblance to membranes now in use in the TO. The membrane w
stalled prior to placing the XM19 mat and was secured by placing bre

anchors at 2-ft intervals. The membrane was placed so as to protrude 6 ft from the mat on all sides (photograph 17). As seen in photograph 18, erosion continued under the membrane. (The parallel wrinkles in the membrane are a result of some displacement of the ramp before the anchor cables became tight.) After this photograph was made, the anchors along the toe of the membrane were pulled out by wave action. The end of the membrane was then buried in a "V" ditch in an attempt to obtain better end anchorage. For photograph 19, the mat was removed to show the depression in the center of the membrane area caused by erosion. The tear in the membrane was caused by traffic action. A sand buildup can be seen under the toe of the membrane. This sand came from the eroded parts of the beach shown in photograph 18. As a result of this test, it was concluded that membrane would reduce beach erosion only when extended larger distances from the edges of the ramp (12 ft). As a result of damages sustained by the underlay, it was concluded that only the most durable materials available should be used and that the toe should be buried rather than pinned when possible. Therefore, heavy-duty, well-anchored membrane extended at least 12 ft on all sides of a ramp will assist in reducing erosion to a small degree.

Traffic loading

17. Tests indicated that the OTB ramp deteriorated in proportion to the number and weight of cargo vehicles that passed over the ramp. The M6 mat sustained no damage after 900 passes of a 1/4-ton truck, as shown in photograph 20, but was distorted after 1400 passes of a 2-1/2-ton truck (photograph 7). It was determined that pierced mats would be unsatisfactory for OTB ramp construction due to their inability to withstand loads imposed by 2-1/2-ton and larger vehicles when these vehicles were loaded to maximum capacity. The 2-1/2-ton truck did not cause any direct damage to the XM19 mat, but the ramp was depressed into scoured areas and buried by eroded sand (photograph 16). Though facilities were not adequate for testing this ramp with a heavier vehicle, it is probable that heavier vehicles would further aggravate this situation and, in addition, cause mat failure in locations where the mat bridged eroded areas. In anticipation of all traffic loadings, these tests indicated that only the most durable mats available should be used as expedient surfacing materials for OTB ramps.

Duration of wave and traffic action

18. Test run 4 was conducted for the purpose of studying the e. of wave duration on an OTB ramp. Photograph 21 shows the beach and r prior to testing. Photograph 22 shows that after 3 hours of wave acti the beach was nearly as severely eroded as in photograph 23 which was after 15 hours of wave action. Serious erosion has taken place under ramp in photograph 23. This test indicated that detrimental effects o waves decreased as a function of time and that the first 1 to 6 hours waves usually caused severe damage. The duration of traffic action in junction with the wave action caused additional damage to the ramp. A parison of photographs 8 and 12 shows additional depression of the mat subsequent burial by sand in an interval from 1400 to 3500 passes of a 2-1/2-ton truck. These tests lea to the conclusion that OTB ramps wil teriorate under continuous action of waves and traffic to a point of ineffectiveness.

Phase II Tests

19. Phase II was conducted for the purposes of studying (a) the fects of vehicle traffic on a bare beach, and (b) the effects of baffle systems on the ramps. The effect of traffic on a bare beach has been d cussed in previous paragraphs and will not be repeated here. Baffle sy tems were studied by installing baffles made of steel weights in variou positions around an M6 ramp and subjecting the beach to wave action. Th steel weights were used to simulate materials available in the TO that could be used as baffling. In conjunction with this test, model barges were placed in the water in front of the ramp to simulate seagoing carg craft and to assist in creating more realistic conditions under which to study effects of the baffles.

Baffle Systems

20. The three basic configurations investigated for the baffles w identified by their orientation as related to the center line of the ram

90 deg, 45 deg, and parallel. Photograph 24 shows the location of 90- and 45-deg baffles with respect to the ramp with the model barge shown in the foreground. Photograph 25 shows parallel 45-deg baffles. In this photograph the model barge has been sunk in order to provide more stability.

21. Tests indicated that a 90-deg baffle would probably be unsuccessful due to the high amount of energy it must absorb from each wave. A more deliberate construction effort would be required for this type of baffle than expedient installation would justify. Photograph 26 shows effects caused on the 90-deg baffle position after 1 hour of wave action. The 45-deg baffle absorbed less energy and, therefore, appeared to maintain its original position after 1 hour of wave action. However, as seen in photograph 27, this configuration permitted infiltration of water and subsequent erosion under the ramp. The parallel baffle remained unmoved during testing but allowed infiltration of water onto the ramp, which caused erosion under the ramp's center. In addition, serious erosion occurred at the toe of the ramp near the baffle as a result of backrush concentration of water between the baffle and model barge. Photograph 28 shows the parallel baffle and ramp after 3 hours of wave action. Photograph 29 shows wave effects on the M6 ramp with barge and without a baffle system. It can be seen that the baffles prevented little, if any, erosion under the M6 ramp. Test results indicated that few benefits were gained from the use of baffles in conjunction with OTB ramps.

PART IV: SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Summary of Results

22. Results of these tests indicate that though none of the experiment surfacing materials seem adequate, XM19 mat underlain with a membrane was more satisfactory than any other materials. Though serious erosion took place under the XM19 ramps, it appeared more capable of carrying required loads than the other mat. The following specific results were obtained.

Landing mats and membranes and beach

23. a. XM19 landing mat was the most nearly adequate of the mats tested.

    b. M6 mat was not satisfactory for OTB ramp construction.

    c. The T16 membrane underlay assisted to a small degree in preventing erosion under the ramp, but the T16 soon sustained serious damages.

    d. The bare beach and the bare, submerged sand beyond the water's edge carried all traffic imposed on it.

Anchors and baffles

24. a. The auger-type anchor was not successful in anchoring OTB ramps.

    b. Deadman-type anchors adequately anchored the ramp when properly installed.

    c. The parallel, 45-deg, and 90-deg baffles tested did not appreciably prevent erosion of the OTB ramp.

    d. Of the three baffle configurations, the 90-deg baffle most nearly prevented erosion of the beach, though it also sustained more damage than the other baffles.

Conclusions

25. Based on the results of this study, the following conclusions are believed adequate:

    a. None of the materials or combinations satisfactorily stabilized the beach foreshore or provided an OTB ramp appreciably better than the natural, bare sand.

b. Benefits gained by installation of any of these OTB ramps were short term due to the rapid deterioration of the ramp foundation.

Recommendations

26. In view of findings presented in this report and as a consequence of other research and correspondence, it is recommended that:

a. An OTB ramp be installed by using existing expedient surfacing materials only after bare beach offloading has proven unsuccessful, and then only for very short-term use.

b. Efforts should be made to establish the need for a design for an OTB ramp at a level between the bare beaches and the hasty use of available materials and the level of permanent piers and docks. If the need for an OTB ramp design is verified, new concepts of expedient ramp construction--such as portable laminated wood decks, armored vehicle-launched bridges, or articulated ramps made of concrete or M4T6 deck balk--should be investigated.

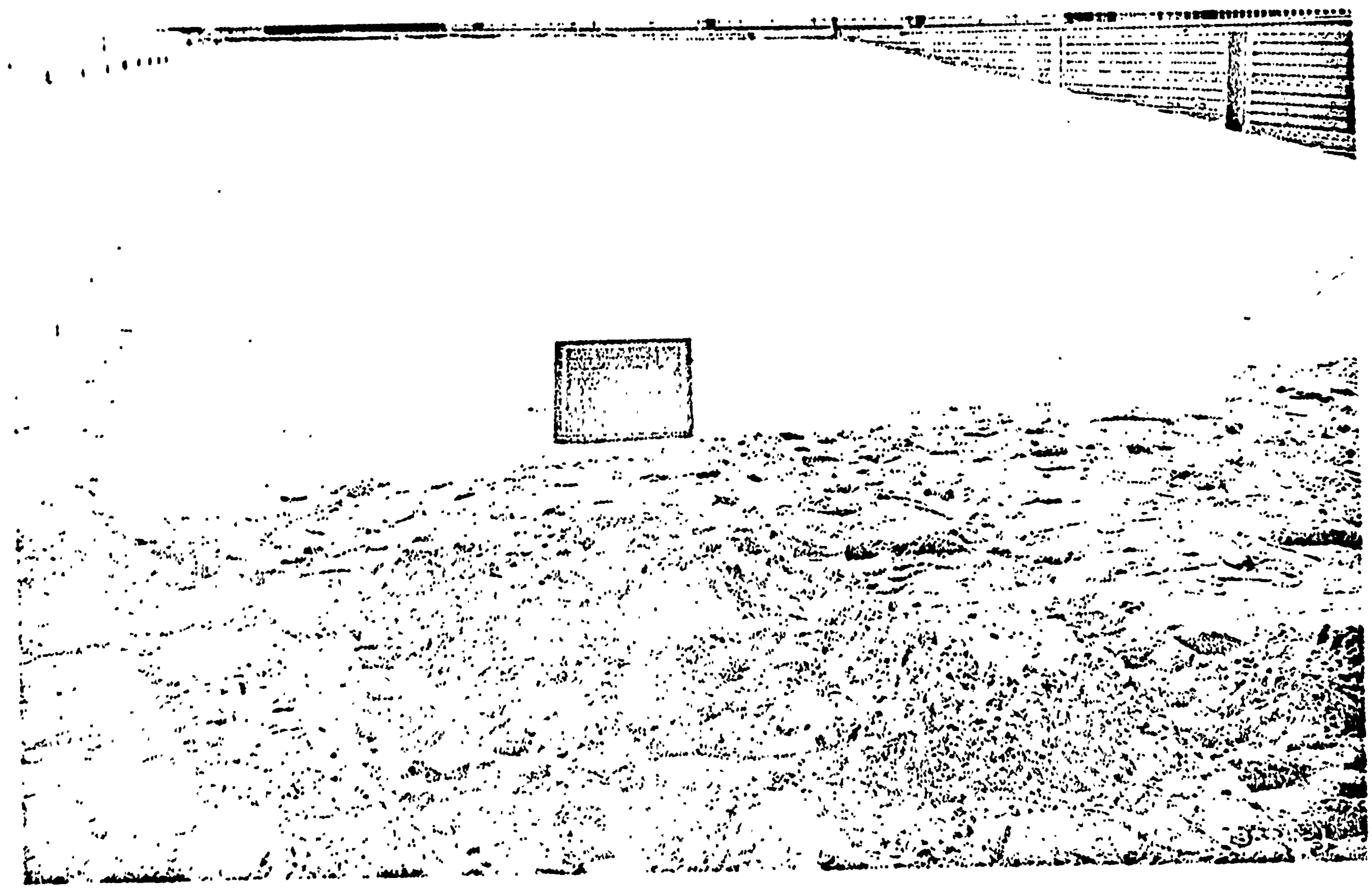
Table 1

Summary of Tests

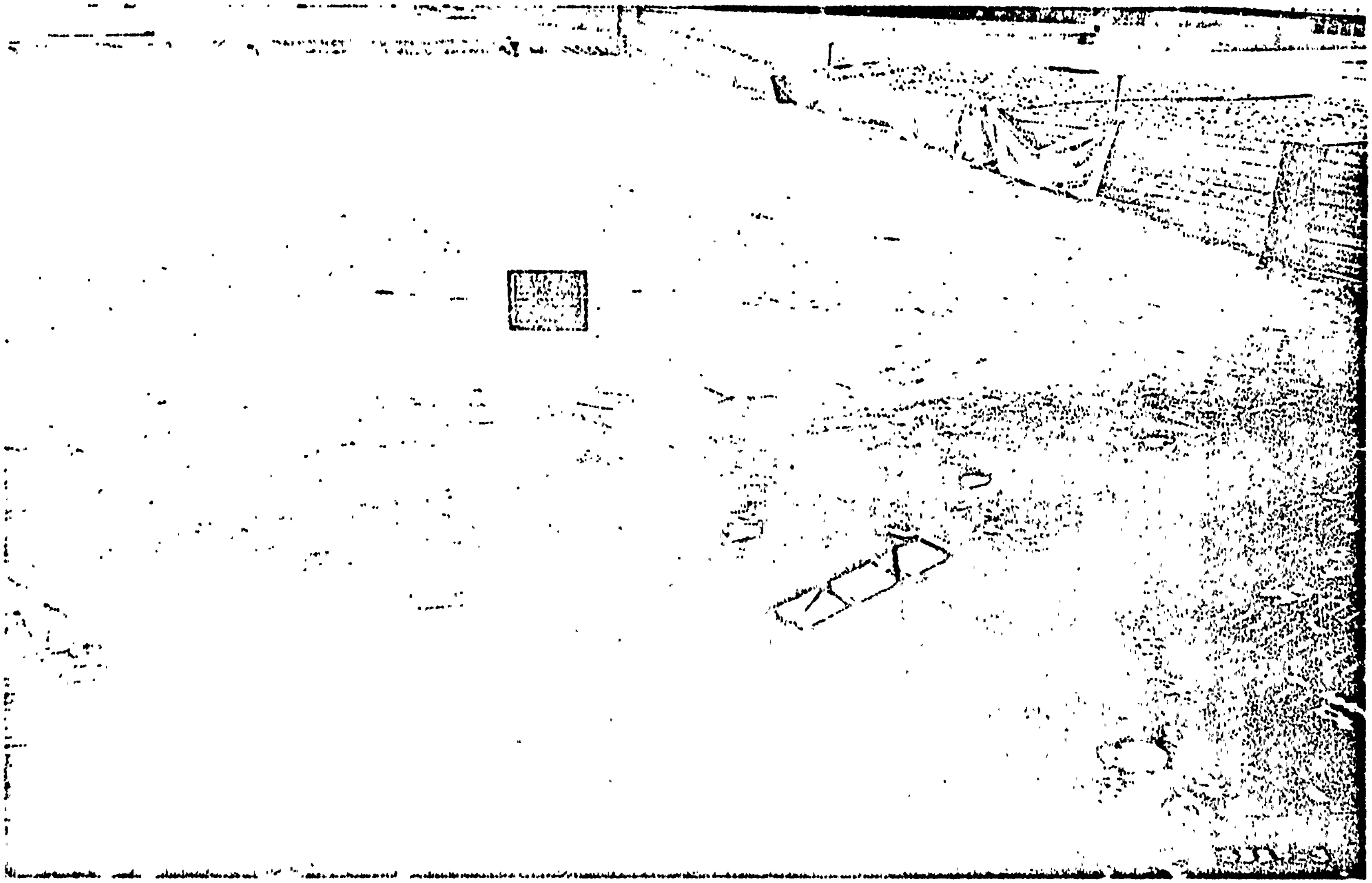
Series*	Slope of Beach %	Test Run No.	Ramp Material	Ramp Width ft	Ramp Location with Respect to Water's Edge	Wave Types**	Wave Duration hr	Traffic Testing: Vehicle Weight ton	Traffic Testing: No. of Passes	Test Results
						Phase I				
1	1[illegible]	1	Bare beach	30	--	1	1	None	None	This test conducted to initially consolidate beach and observe natural slope of beach
		2	"	1[illegible]	Buried 1 ft short of water's edge	1	1	1/4	[illegible]00	Slight erosion under ramp and subsequent burial by sand. Mat not tested to failure
		3	"	20	Buried 1 ft short of water's edge	1	3	1/4	1530	Severe erosion under ramp and at end of ramp as a result of wave [illegible]
		4	"	20	Buried [illegible] ft beyond water's edge	1	15	None	None	Severe erosion under ramp and at end of ramp. Severe excessive sand deposition on top of ramp
		5	"	20	Buried [illegible] ft beyond water's edge	1	2-1/2	2-1/2	1[illegible]00	Erosion under ramp and mat damage as a result of vehicle loading
		6	[illegible]	12	Buried 1 ft short of water's edge	1	3	2-1/2	422	Mat settlement and displacement due to traffic loading. Toe of ramp buried in sand
		7	[illegible] with auger-type anchors	12	Buried [illegible] ft beyond water's edge	1	5	2-1/2	[illegible]	A[illegible] tested. Immediate failure of auger-type anchors. Mat settlement
2	2[illegible]	8	"	10	Buried at water's edge	1	1/2	1/4	350	Beach immediately reverted to natural slope of 10%. Severe erosion under ramp
		9	Bare beach	30	--	1, 2, 3	1 (each type)	None	None	Conducted to compare effects of various wave types. All wave types formed natural beach slope of 10%
		10	[illegible]	12	Buried [illegible] ft beyond water's edge	1, 2, 3	1 (each type)	None	None	
		11	[illegible] with deadman-type anchors and 1/16 membrane underlay	12	Buried [illegible] ft beyond water's edge	1	3	2-1/2	1600	Test effects of membrane underlay. Membrane was damaged by vehicle but prevented erosion to a small extent
		12	[illegible] with deadman-type anchors	12	Extended approximately [illegible] ft beyond water's edge	1	1.3	2-1/2	400	Mat extended 35 ft beyond water's edge. Slightly increased trafficability underwater
						Phase II				
--	--	1	Bare beach	30	--	1	2-1/2	None	None	Study of natural beach erosion pattern. Waves formed 10% beach slope without serious erosion
		2	Bare beach	30	--	1	4	1/4	588	Test of ability of bare beach to carry traffic. Bare beach proved capable of carrying traffic
		3	[illegible] with baffles	1[illegible]	Buried at water's edge	1	1	None	None	90° baffle helped prevent erosion but sustained serious damage
		4	[illegible] with baffles	1[illegible]	Buried at water's edge	1	3	None	None	45° and parallel baffles did not appreciably prevent erosion
		[illegible]	[illegible] with baffles	[illegible]	Buried at water's edge	1	3	None	None	[illegible]° baffles did not appreciably prevent erosion
		[illegible]	[illegible]	[illegible]	[illegible] water's	1	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

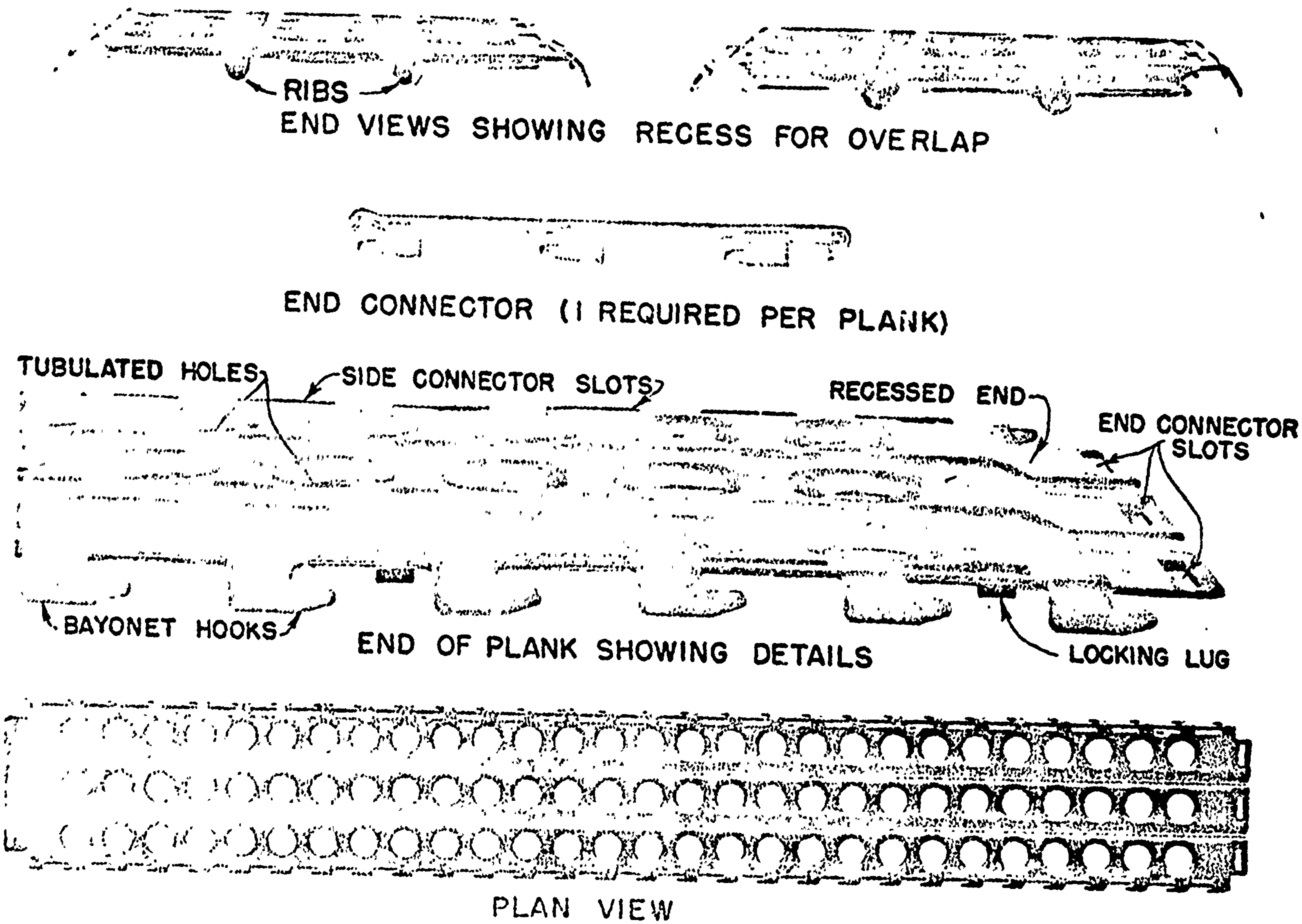
** [illegible]



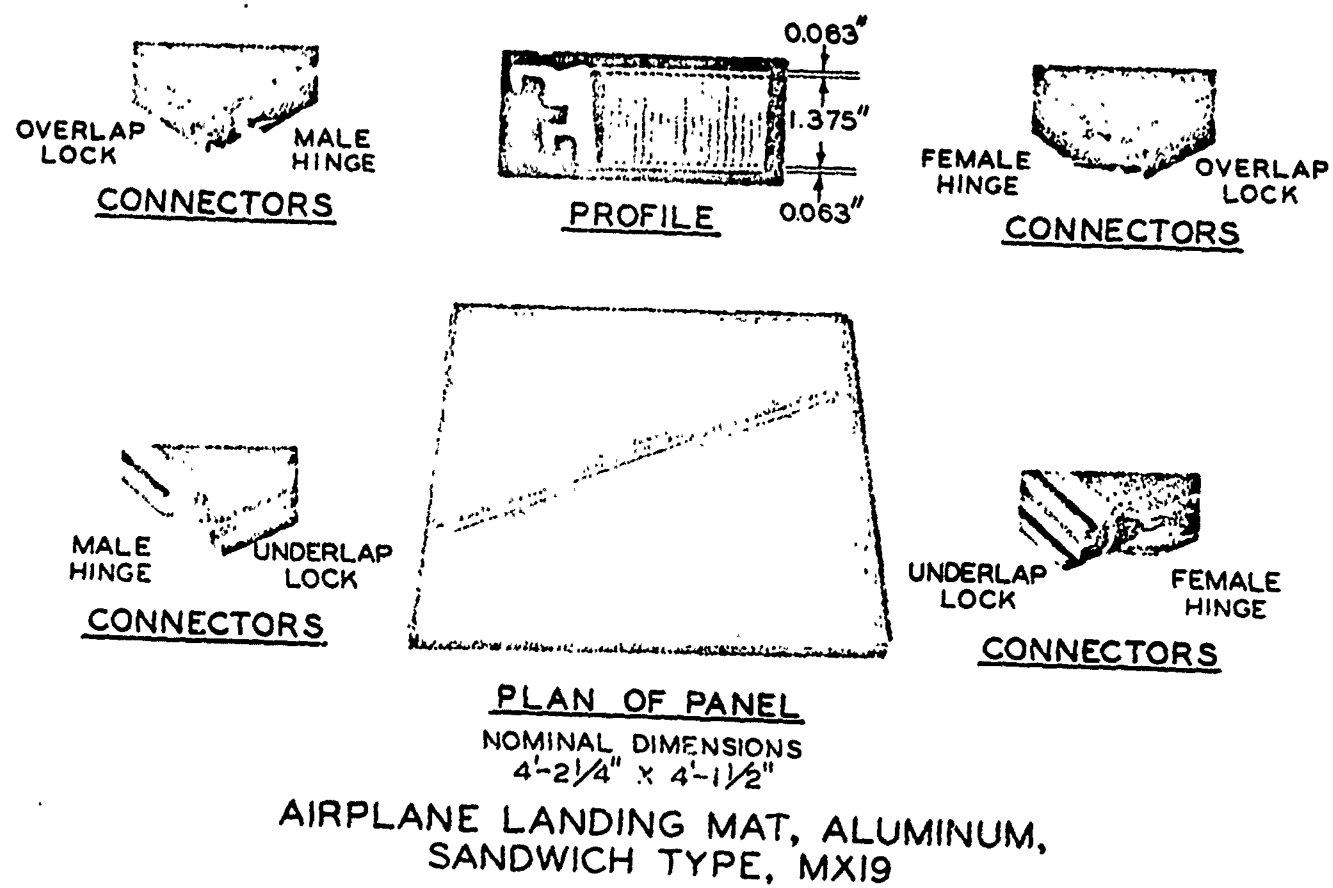
Photograph 1. Sand beach prior to test run 1



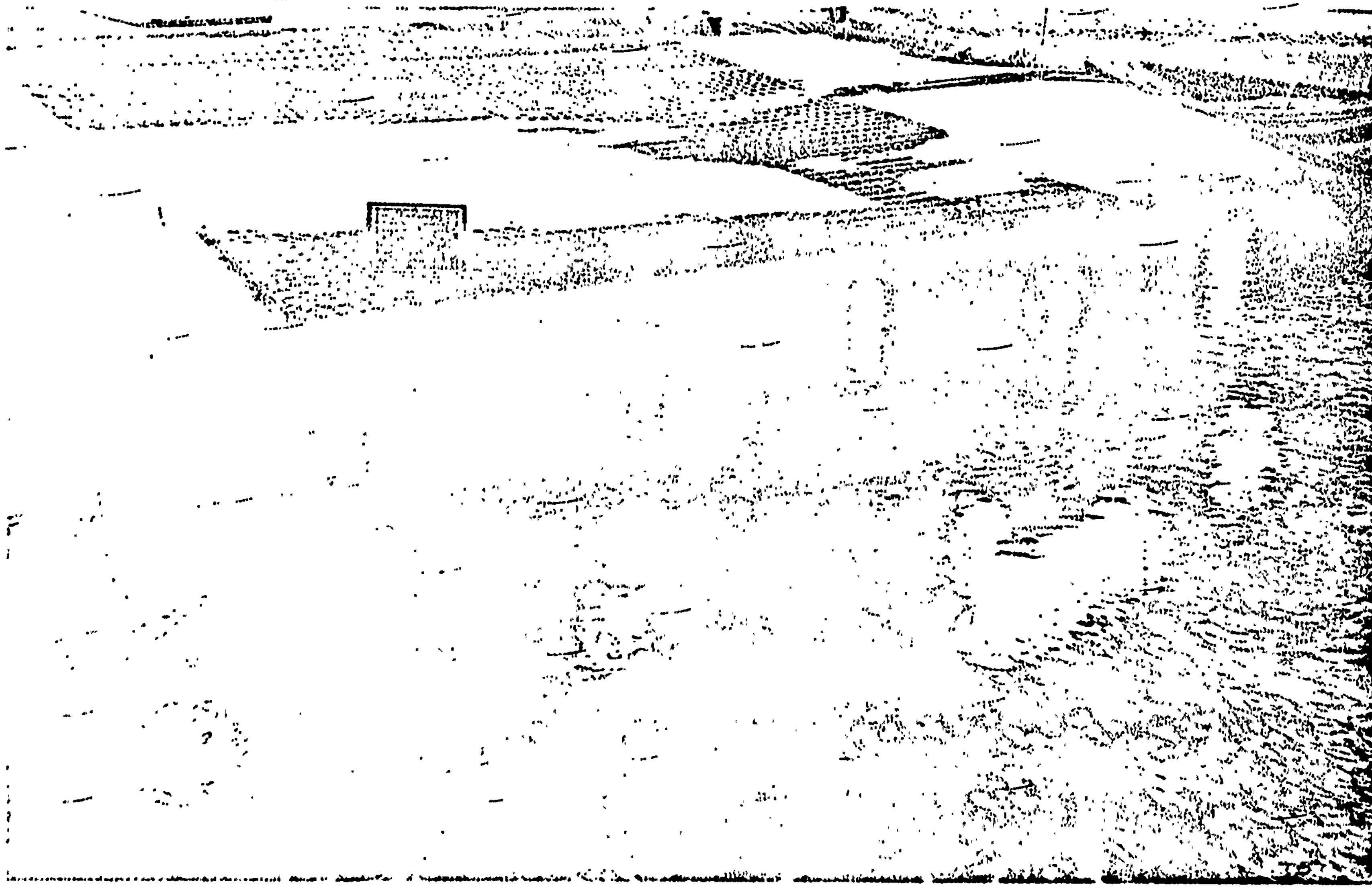
Photograph 2. Sand beach with wave tank filled, ready for placement of ramp for test run 1



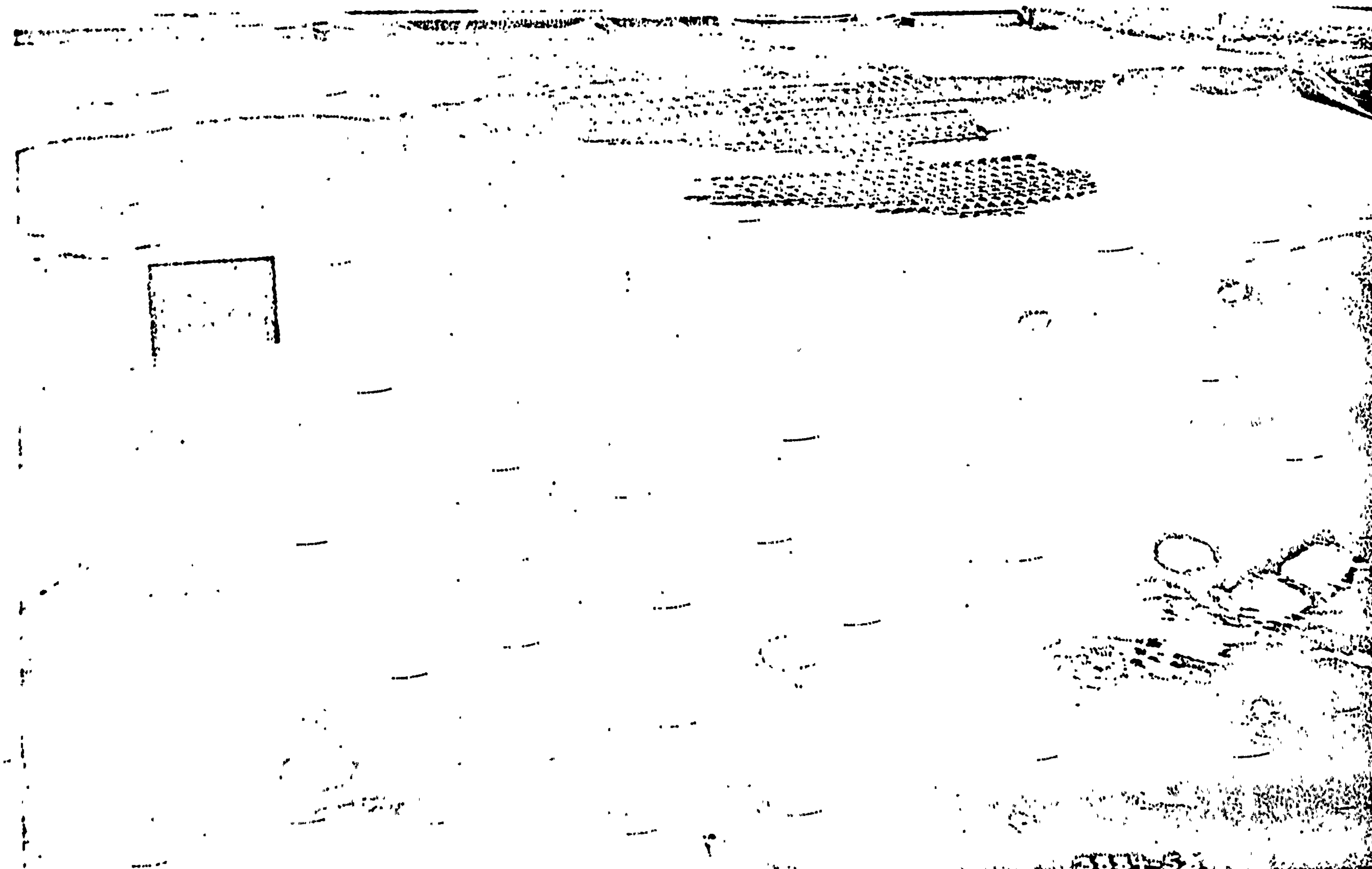
Photograph 3. M6 mat



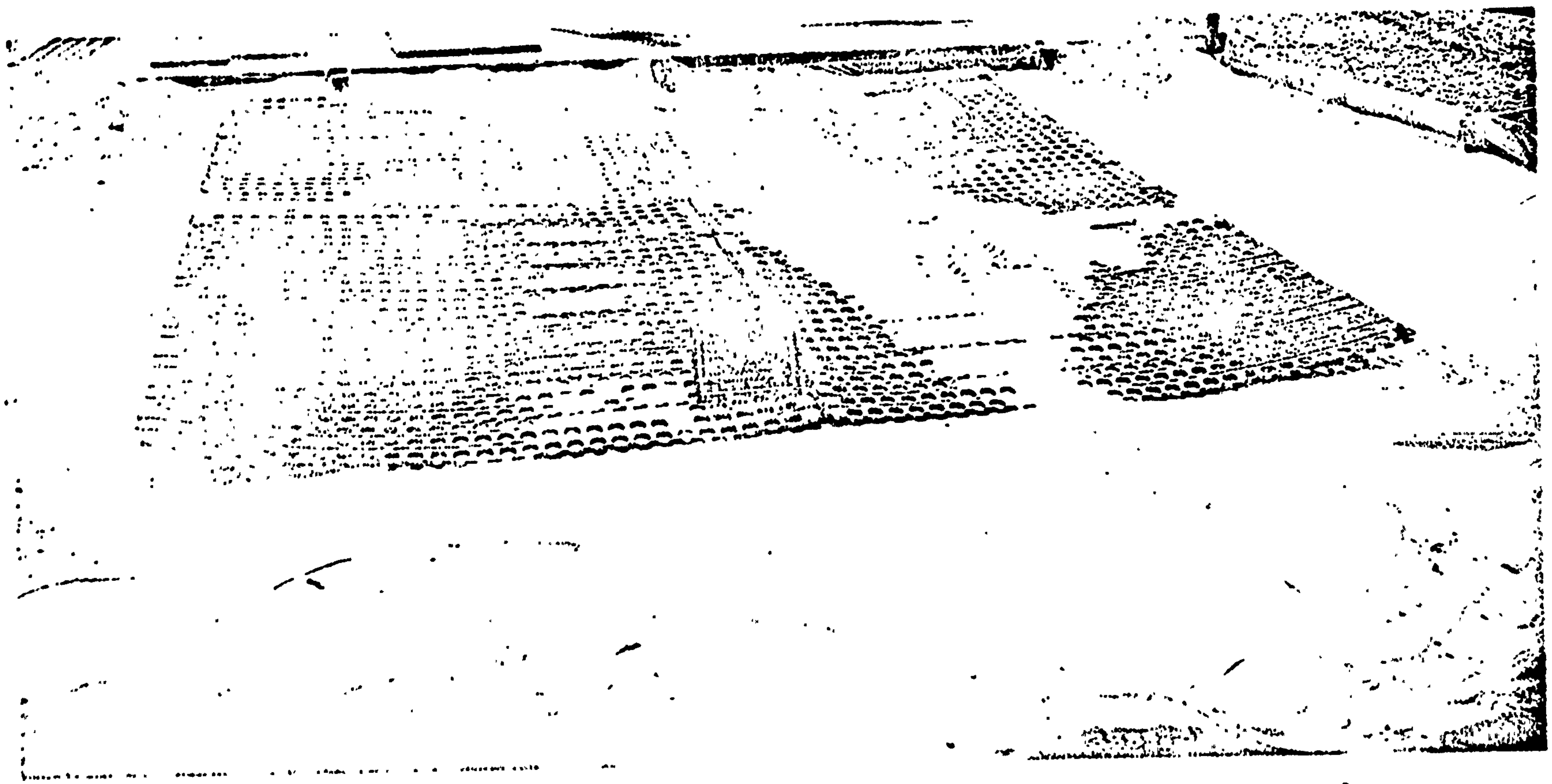
Photograph 4. XM19 aluminum landing mat



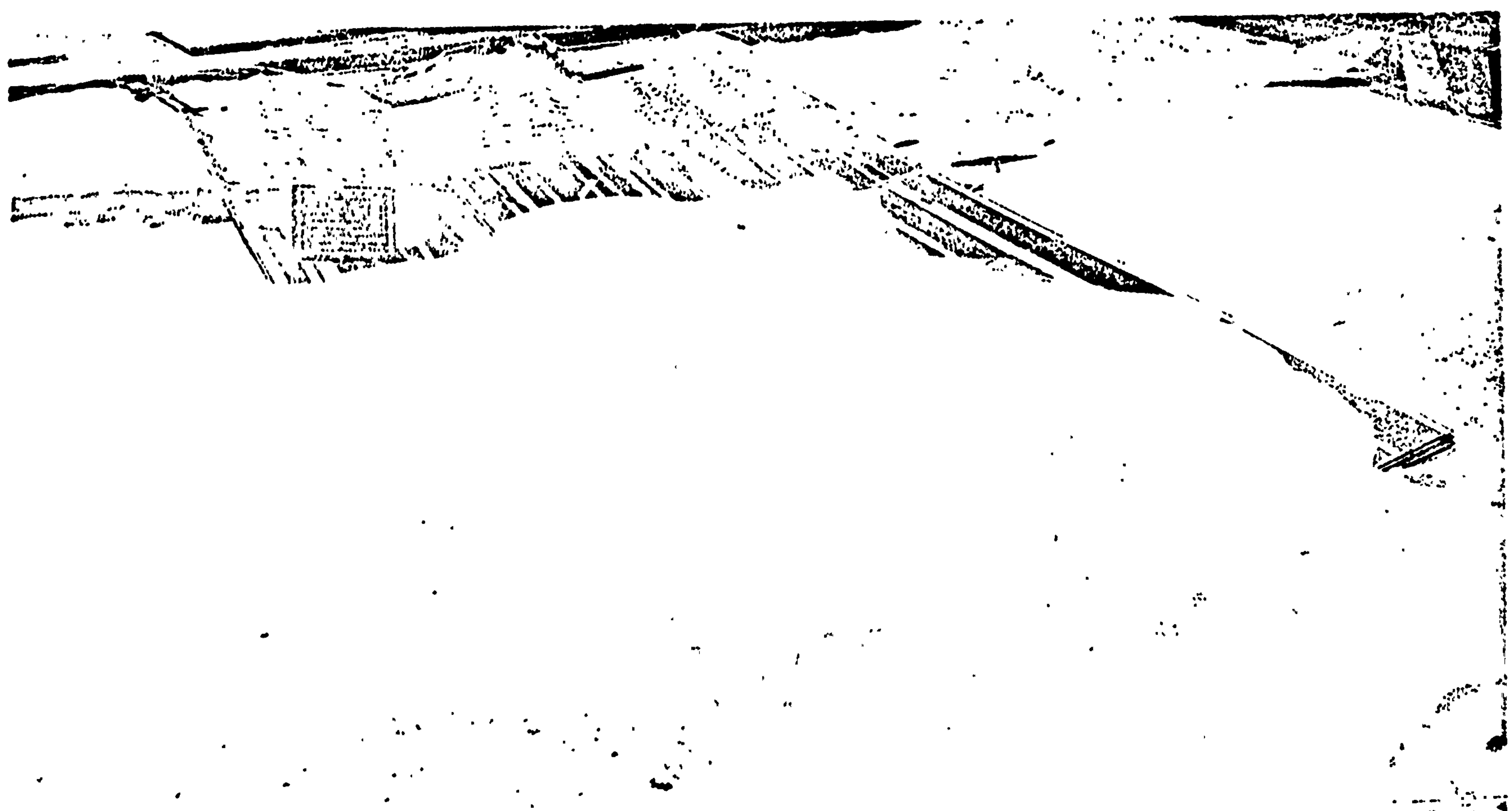
Photograph 5. Test run 4. Beach erosion under M6 mat after 15 hr, wave type 1 (10% slope)



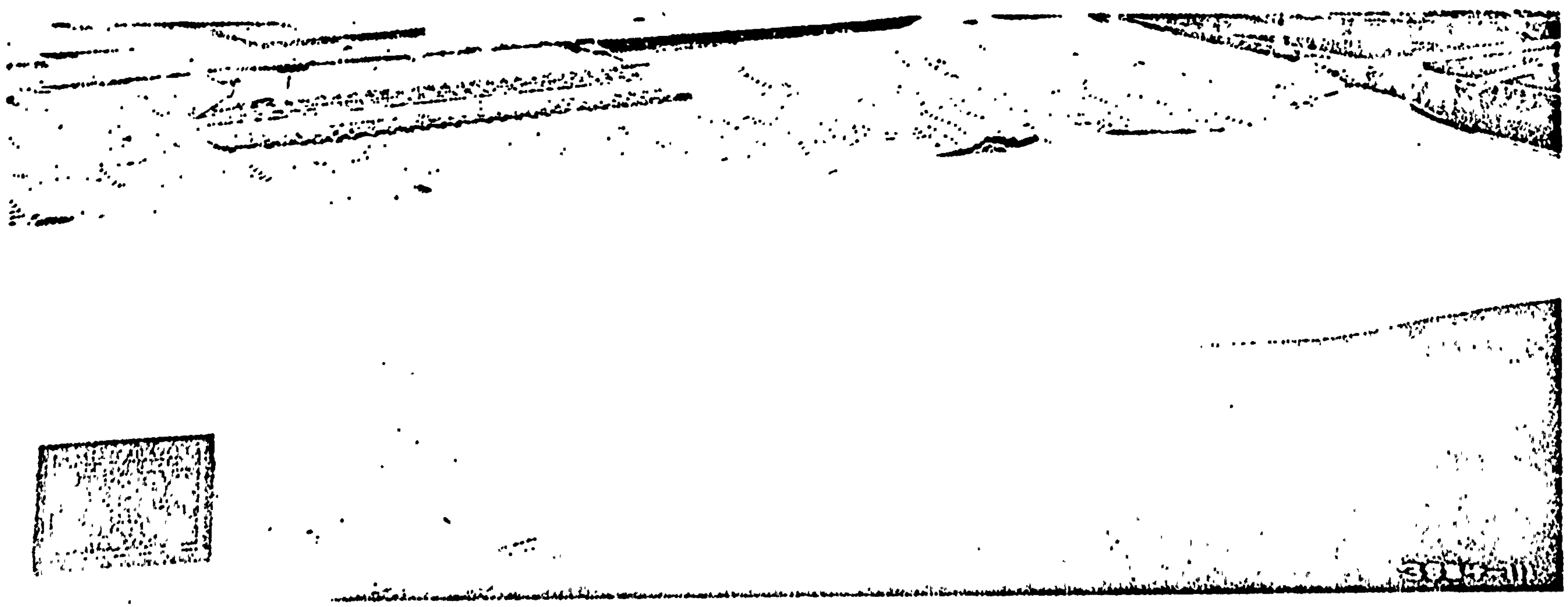
Photograph 6. Test run 8. Beach erosion under M6 mat after 30 min, wave type 1 (20% slope)



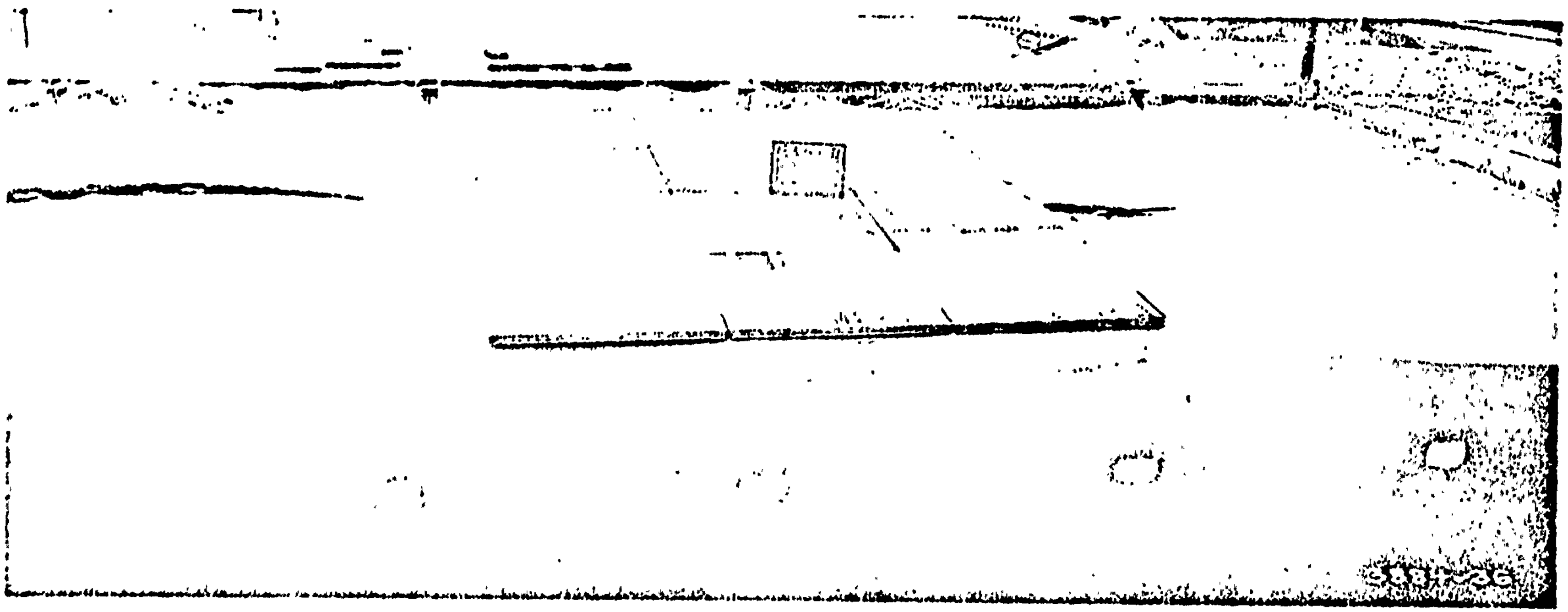
Photograph 7. Test run 5. Condition of M6 ramp and beach after wave action and 1400 passes of 2-1/2-ton truck



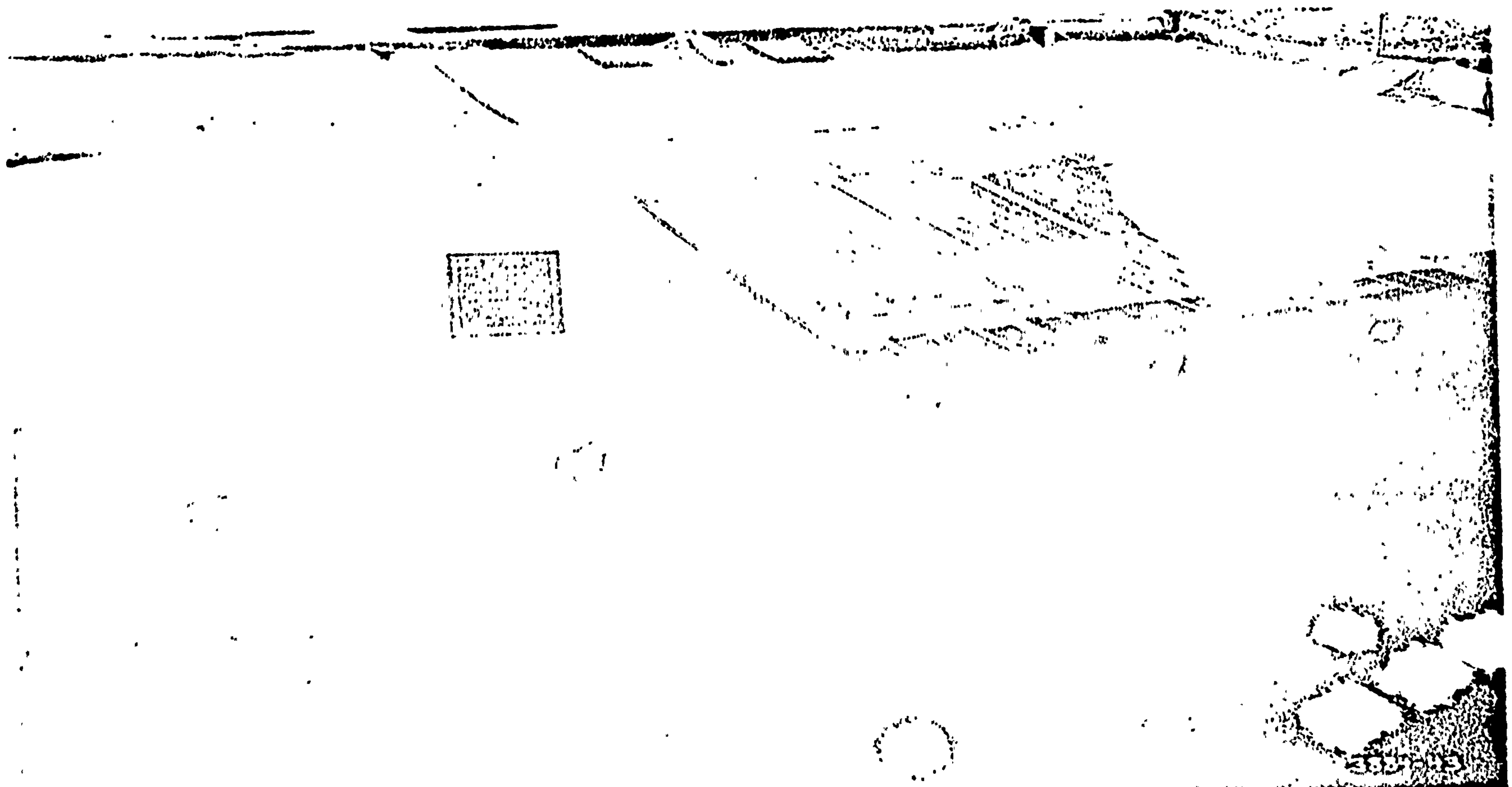
Photograph 8. Test run 7. Condition of XM19 ramp and beach after wave action and traffic



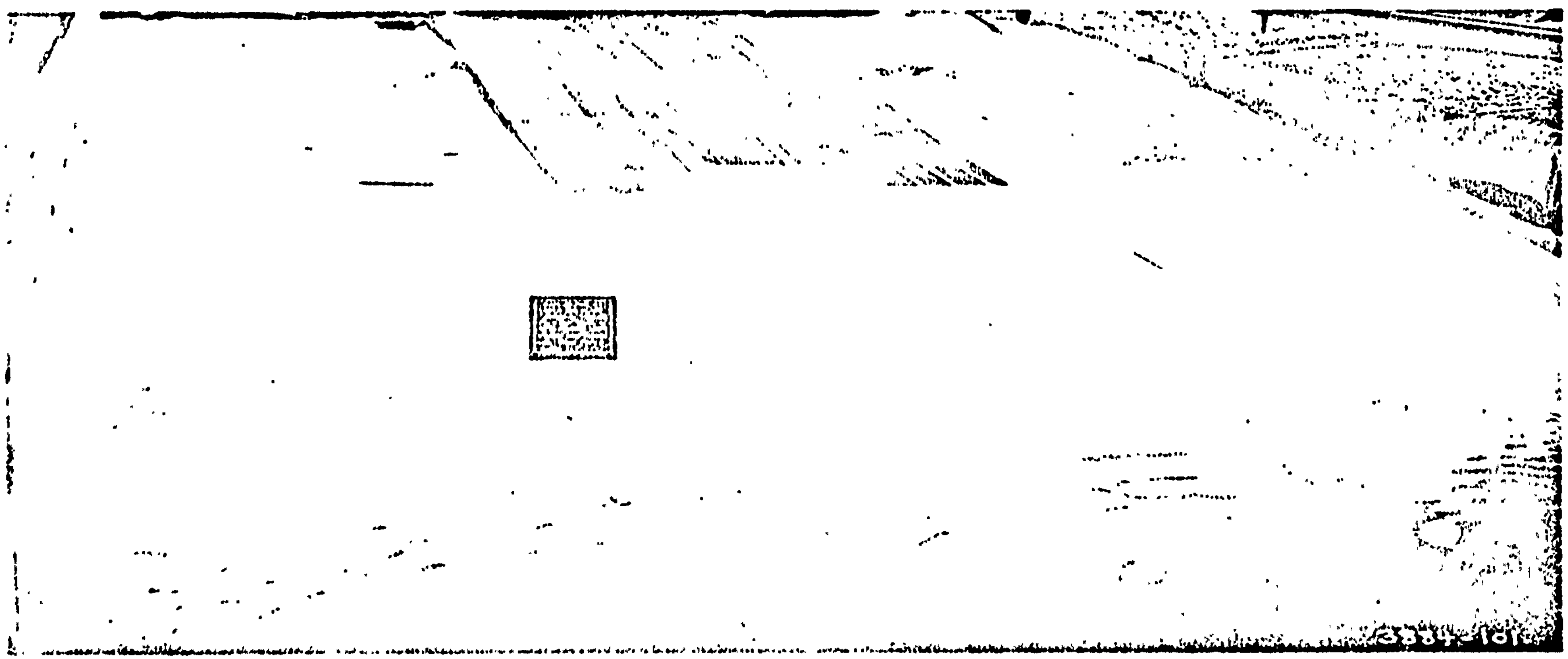
Photograph 9. Phase II, test 2. Condition of bare beach after wave action and traffic



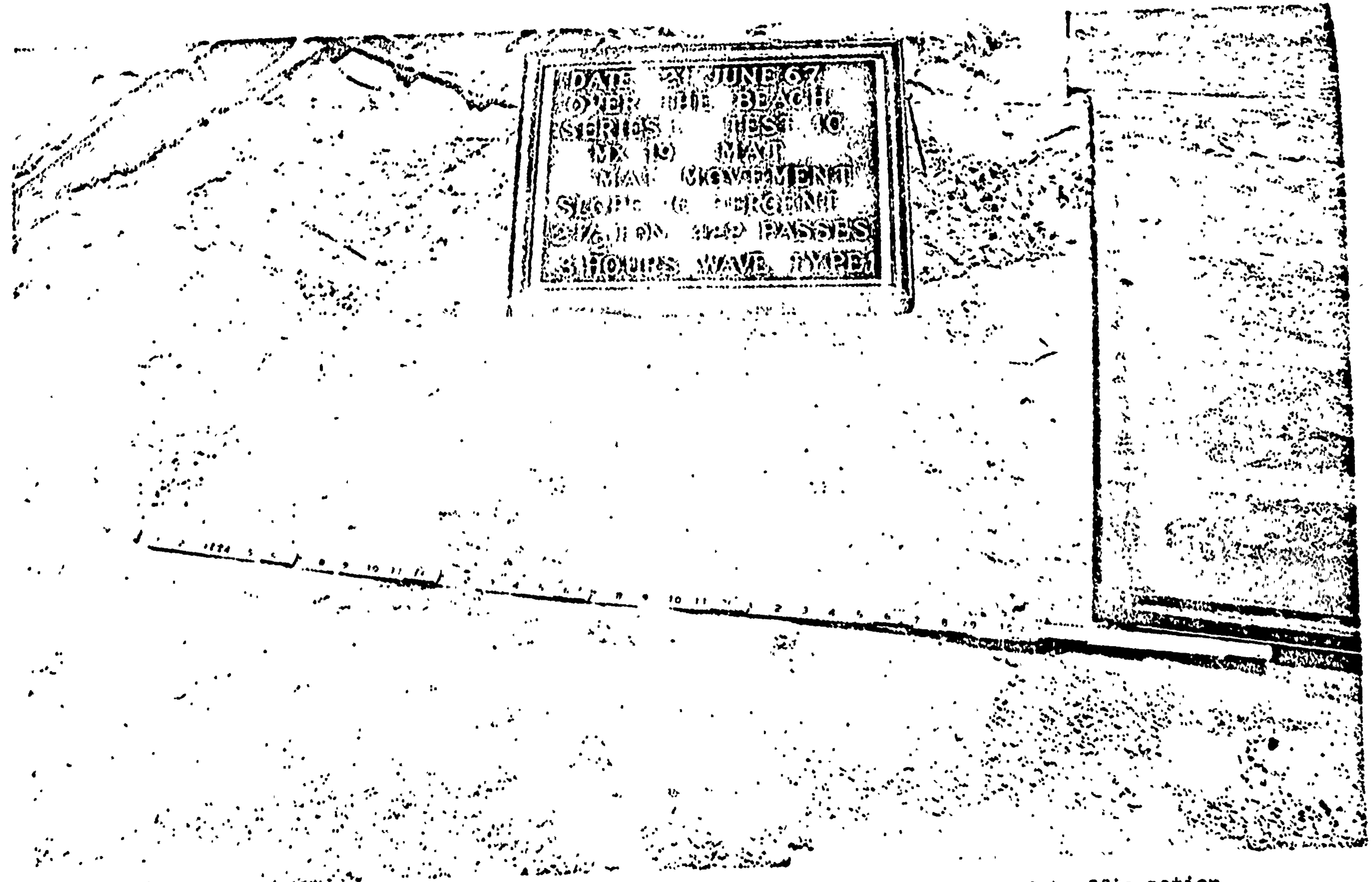
Photograph 10. Test run 6. Erosion pattern of beach when XM19 ramp ended 1 ft short of water's edge



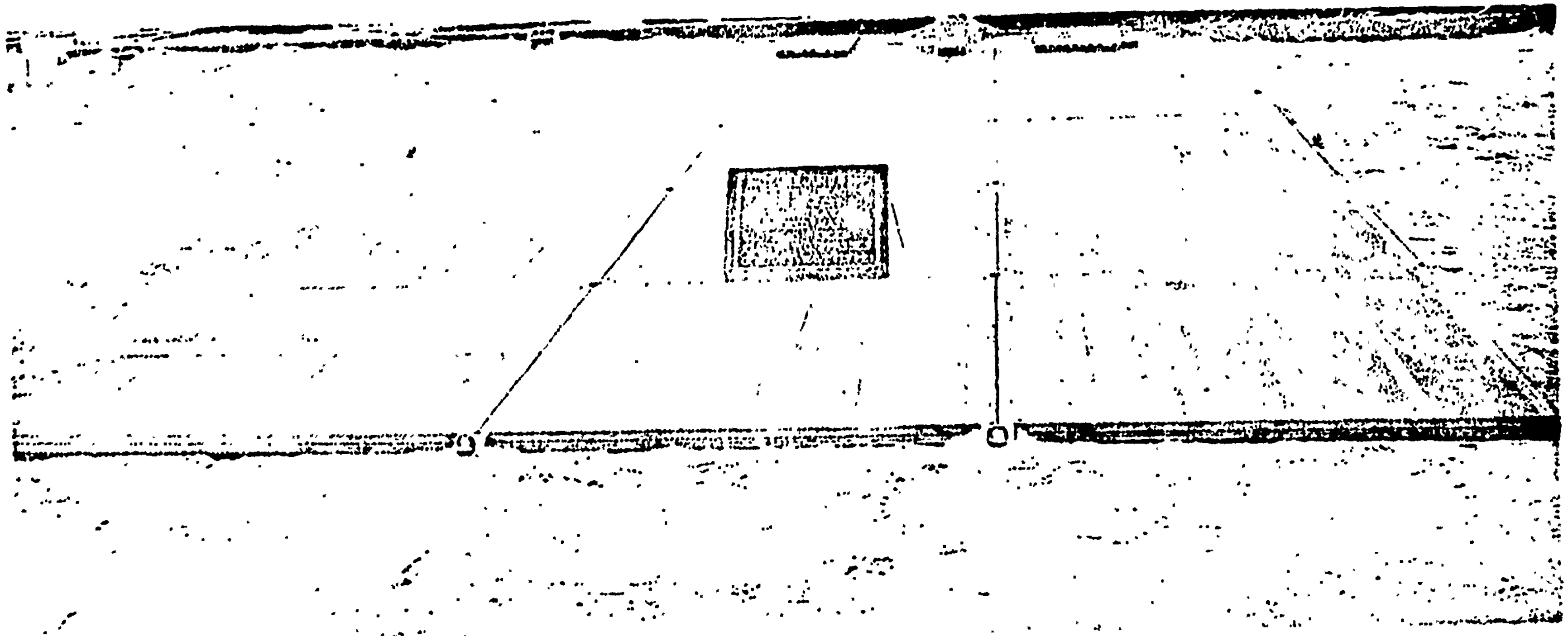
Photograph 11. Test run 7. Erosion pattern under XM19 ramp ended 3 ft beyond water's edge



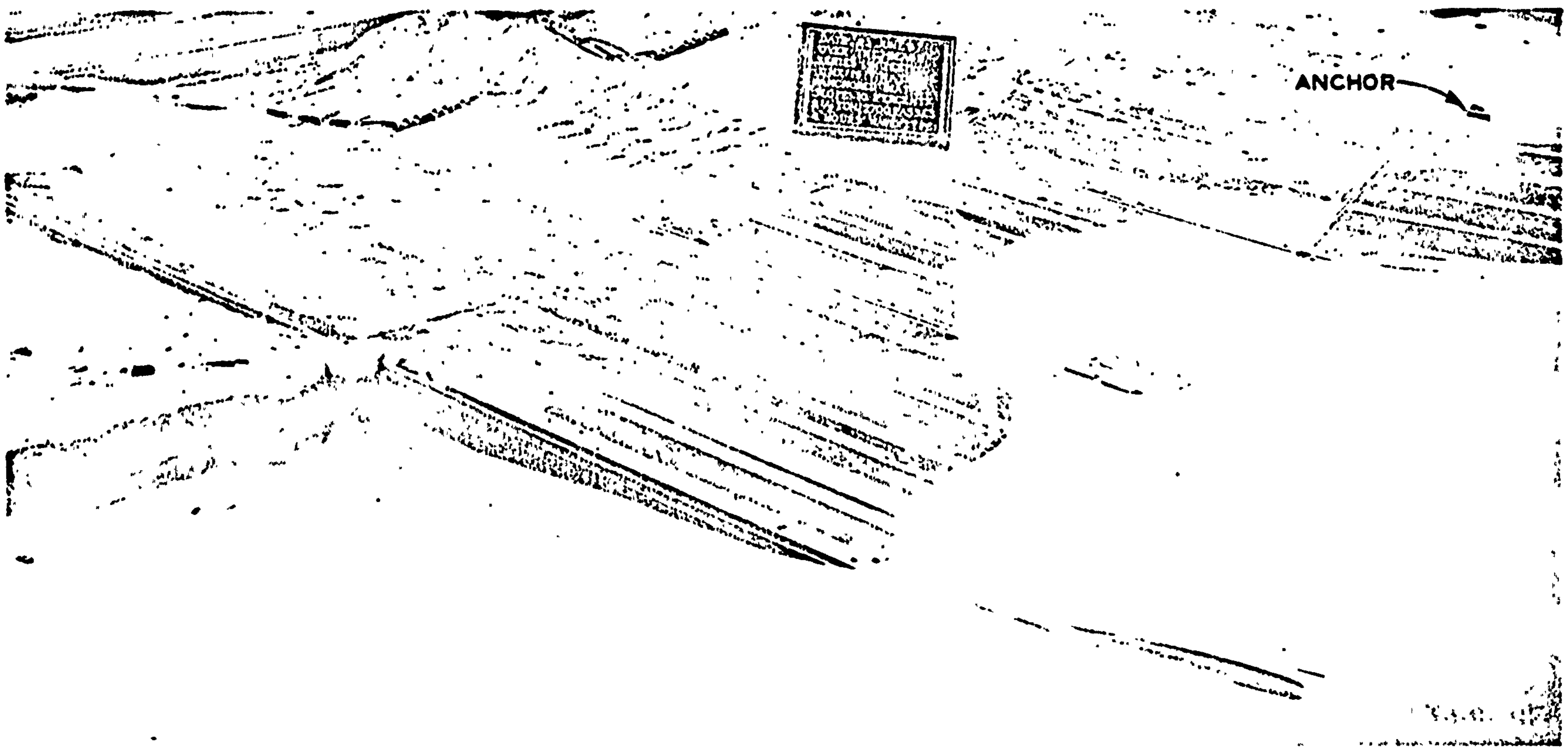
Photograph 12. Test run 12. XM19 ramp extended 35 ft beyond water's edge (tank drained for this photograph)



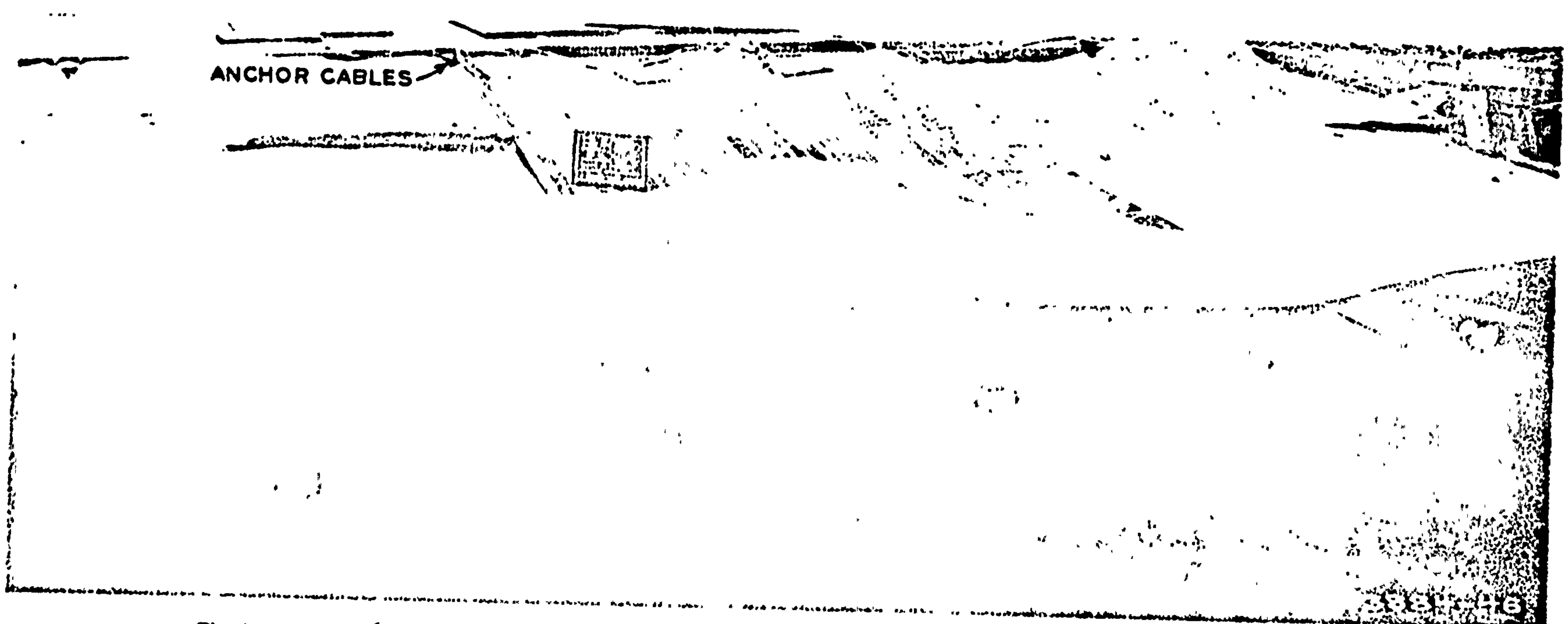
Photograph 13. Test run 6. Displacement of XM19 ramp as a result of traffic action



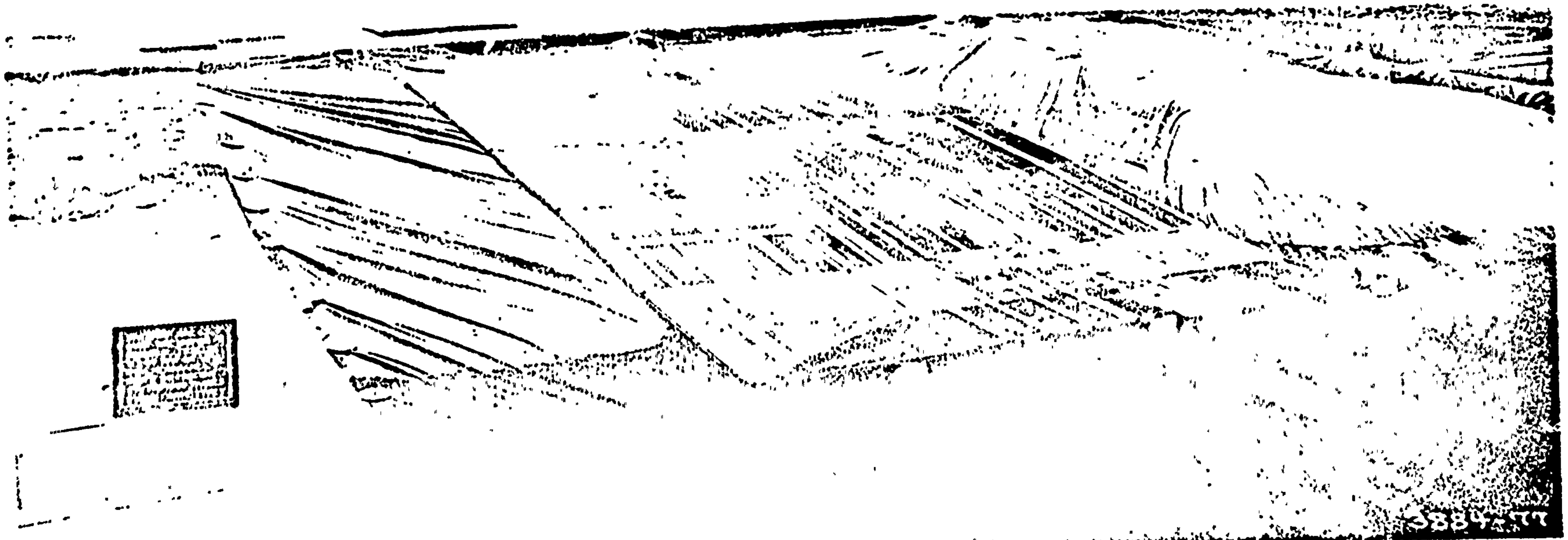
Photograph 14. Test run 7. Auger-type anchors installed at toe and sides of XM19 ramp



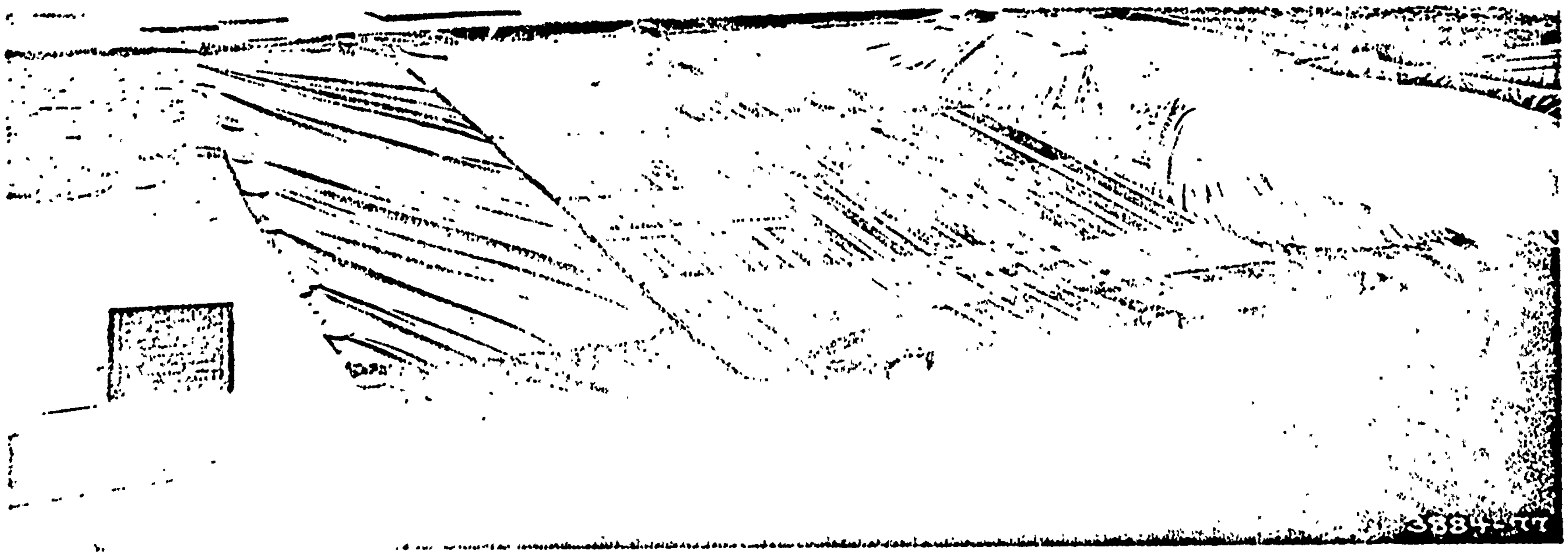
Photograph 15. Test run 7. Disengaged auger-type anchor (upper right)



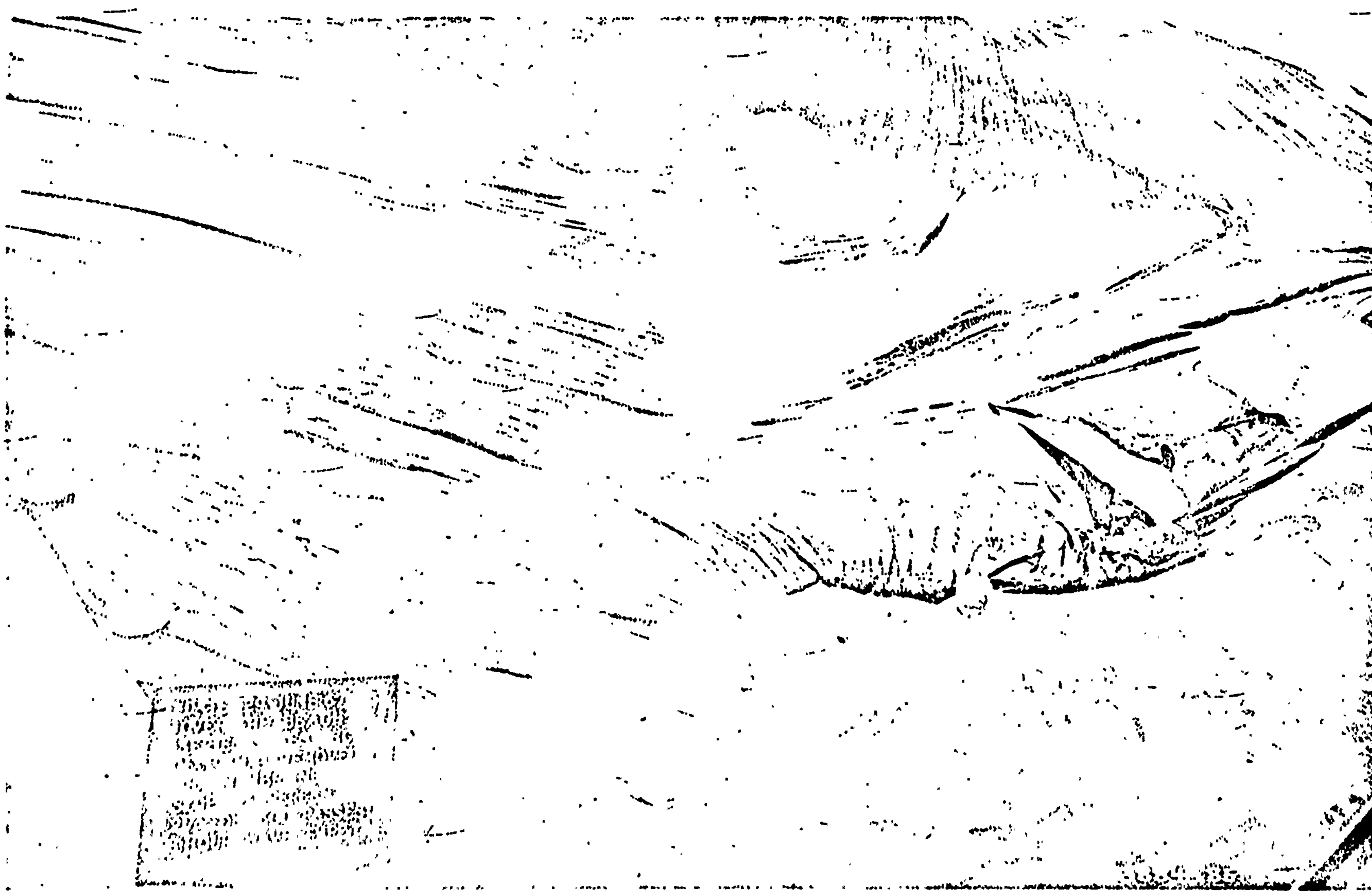
Photograph 16. Test run 7. Simulated deadman-type anchors (top center) employing cables through holes in XM19 mat



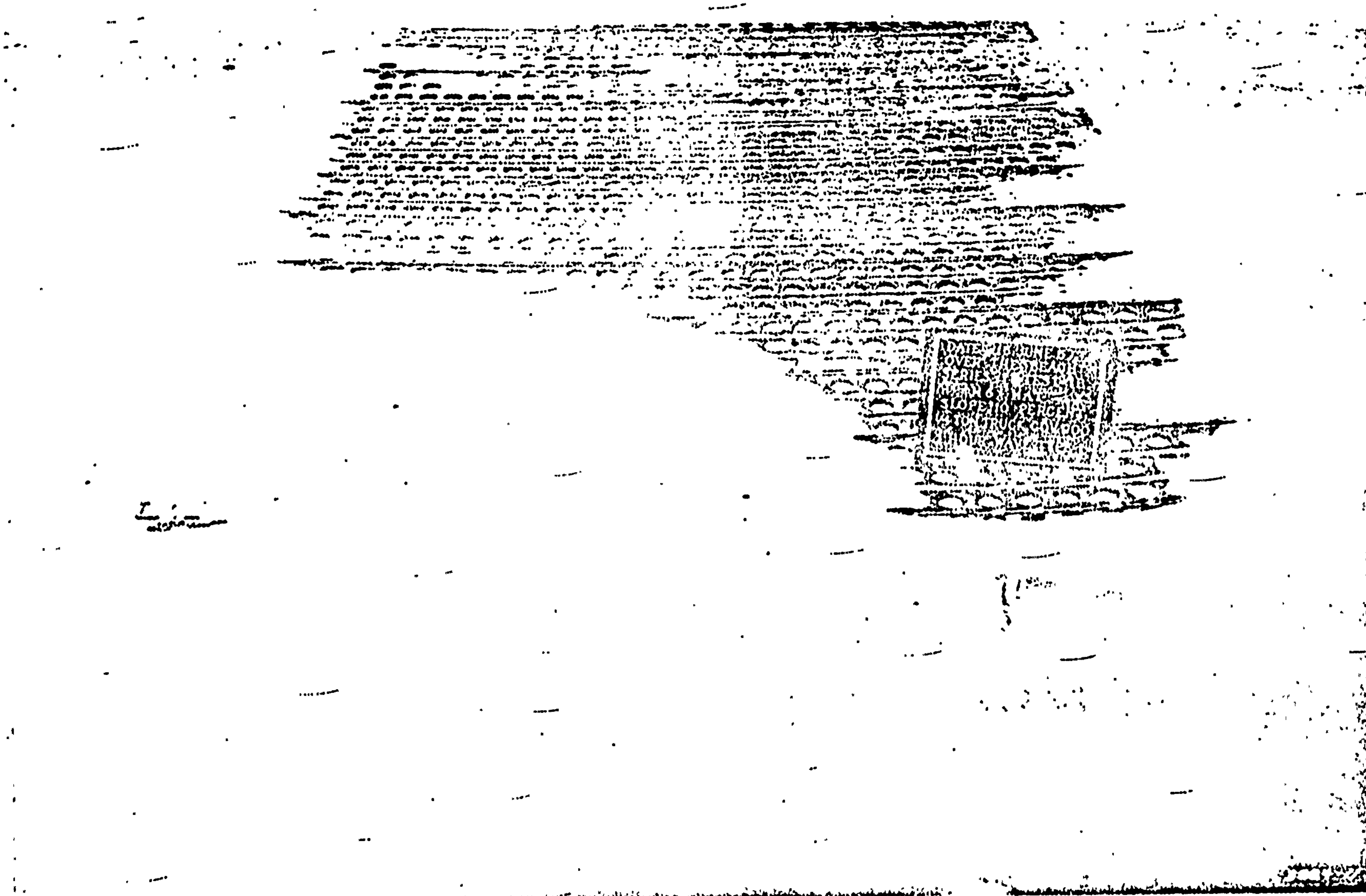
Photograph 17. XM19 mat ramp with T16 membrane underlay and deadman-type anchors, ready for test run 11



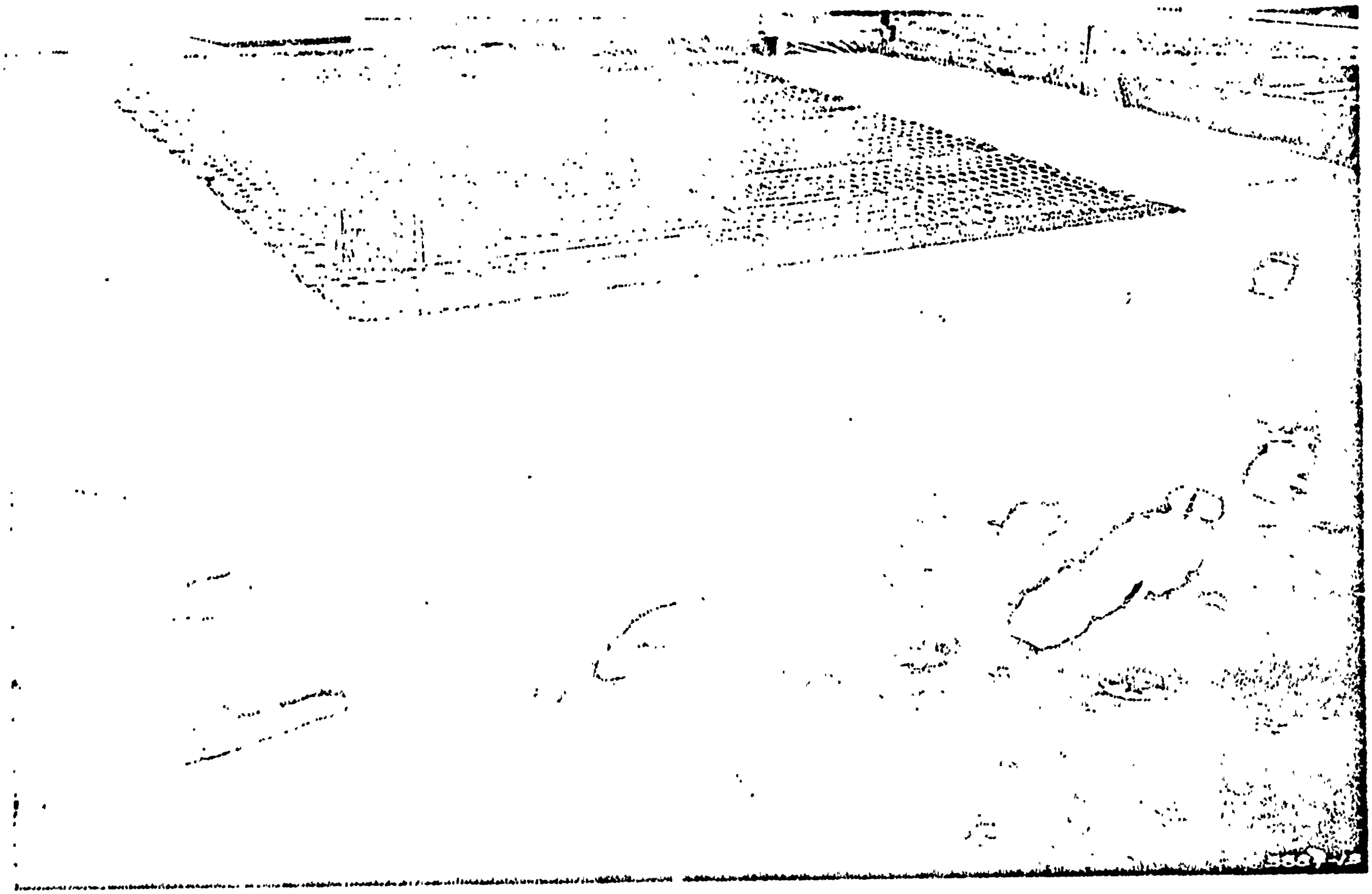
Photograph 18. Test run 11. Continued erosion of the beach after installation of T16 membrane underlay



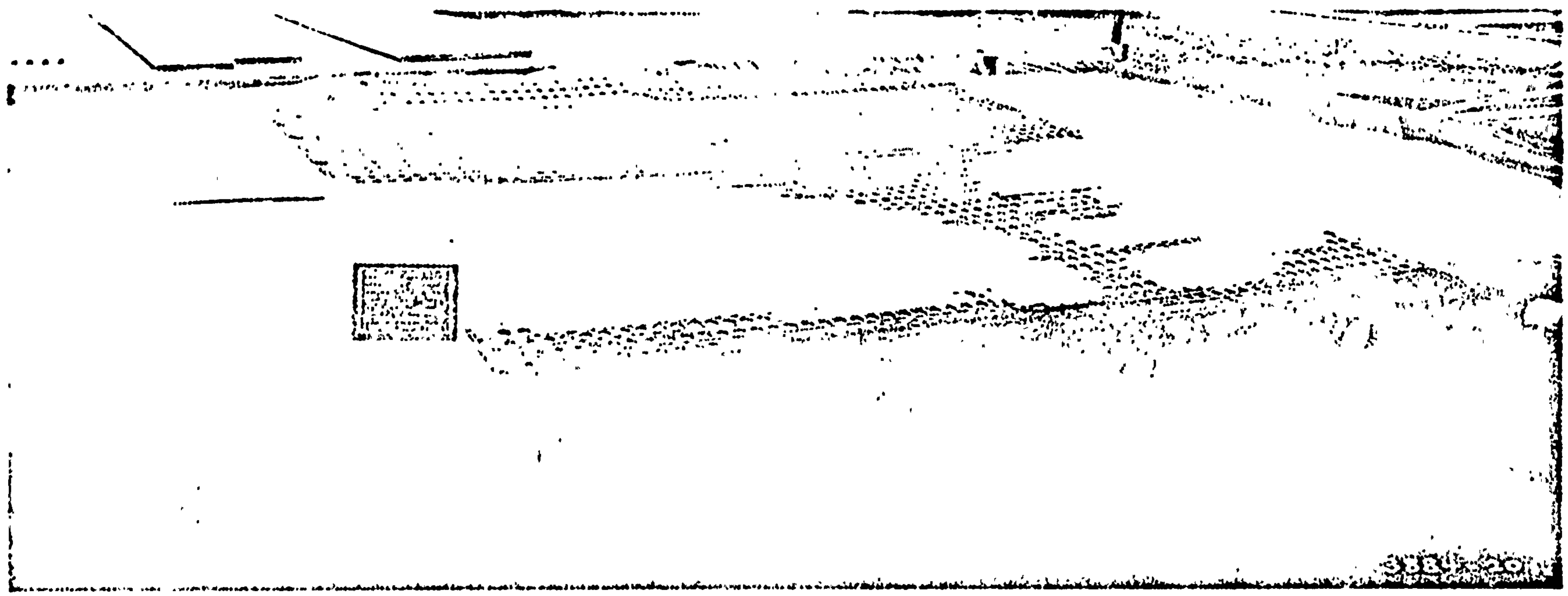
Photograph 19. Test run 11. Failure of the T16 membrane underlay



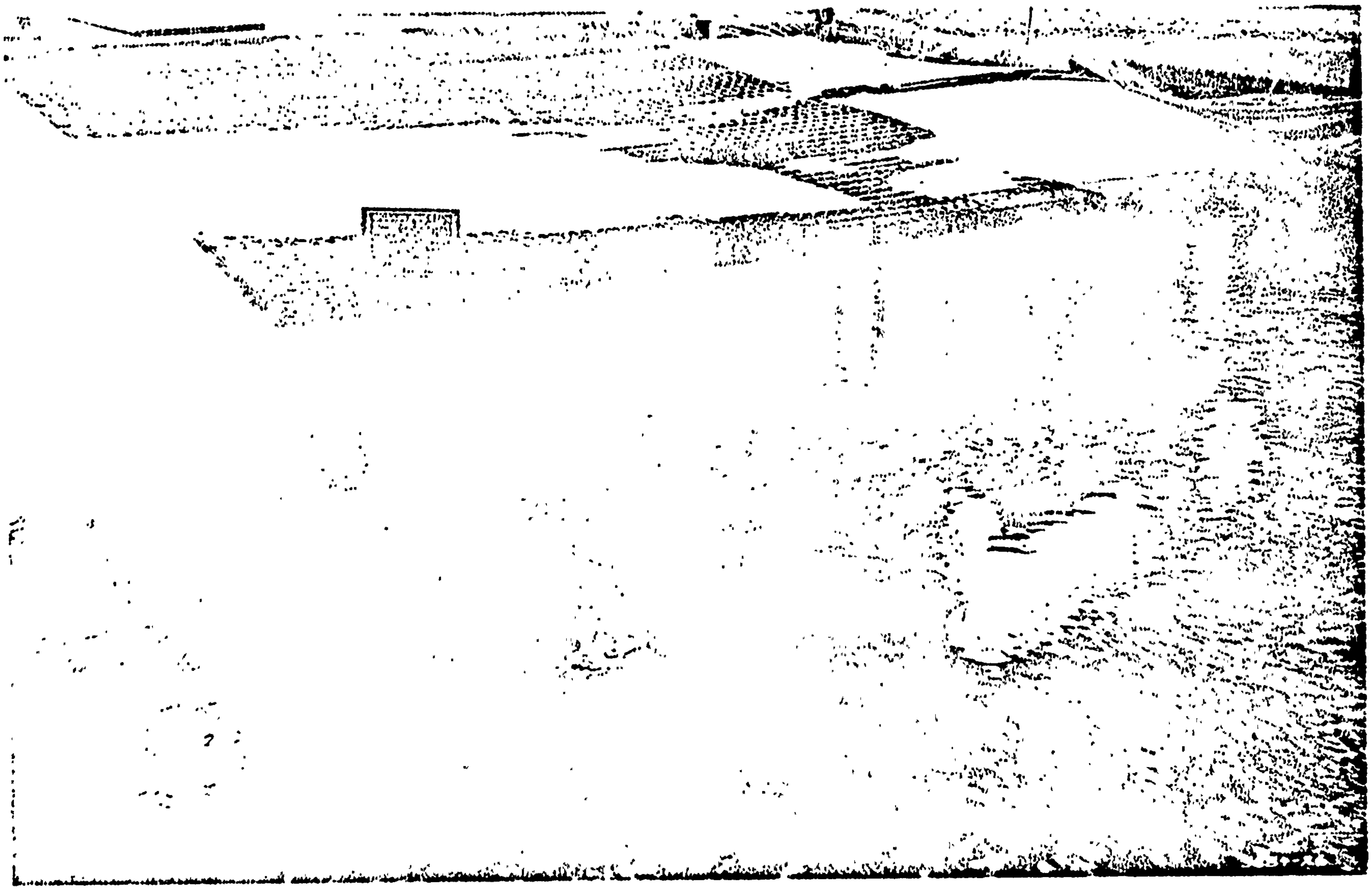
Photograph 20. Test run 2. Condition of ramp after 900 passes of 1/4-ton truck



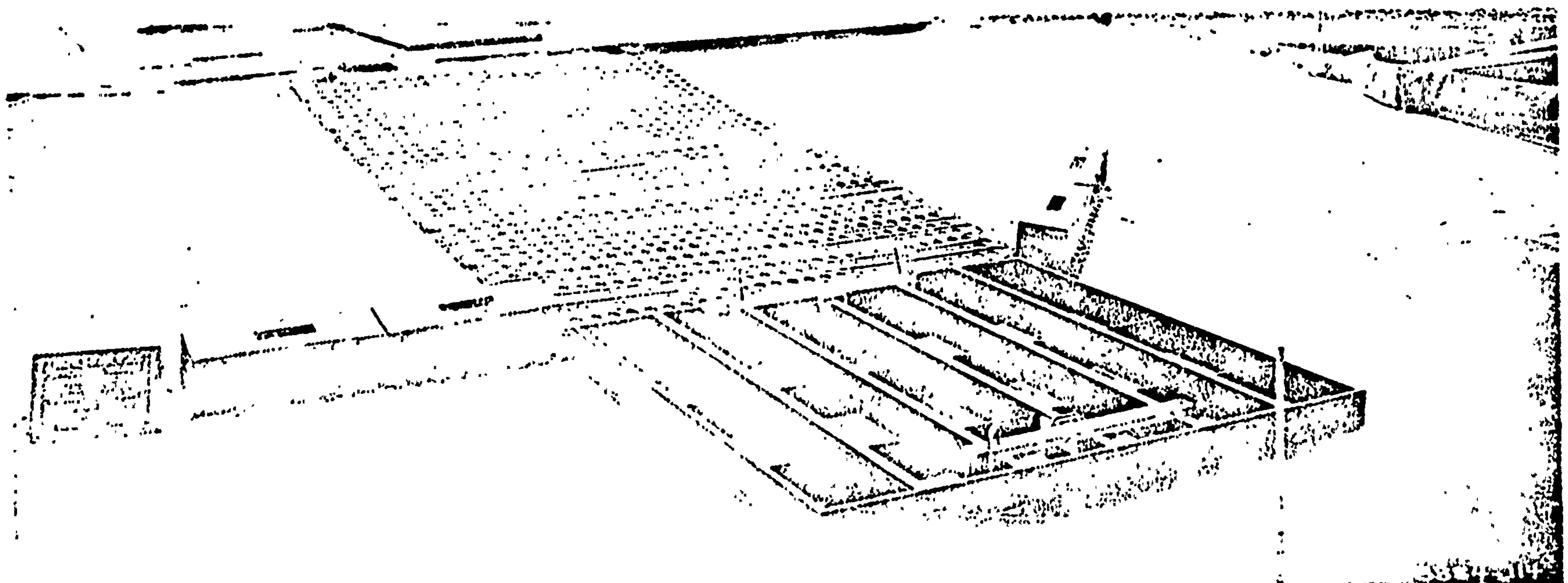
Photograph 21. Test run 4. Beach and M6 ramp prior to testing for effect of wave duration



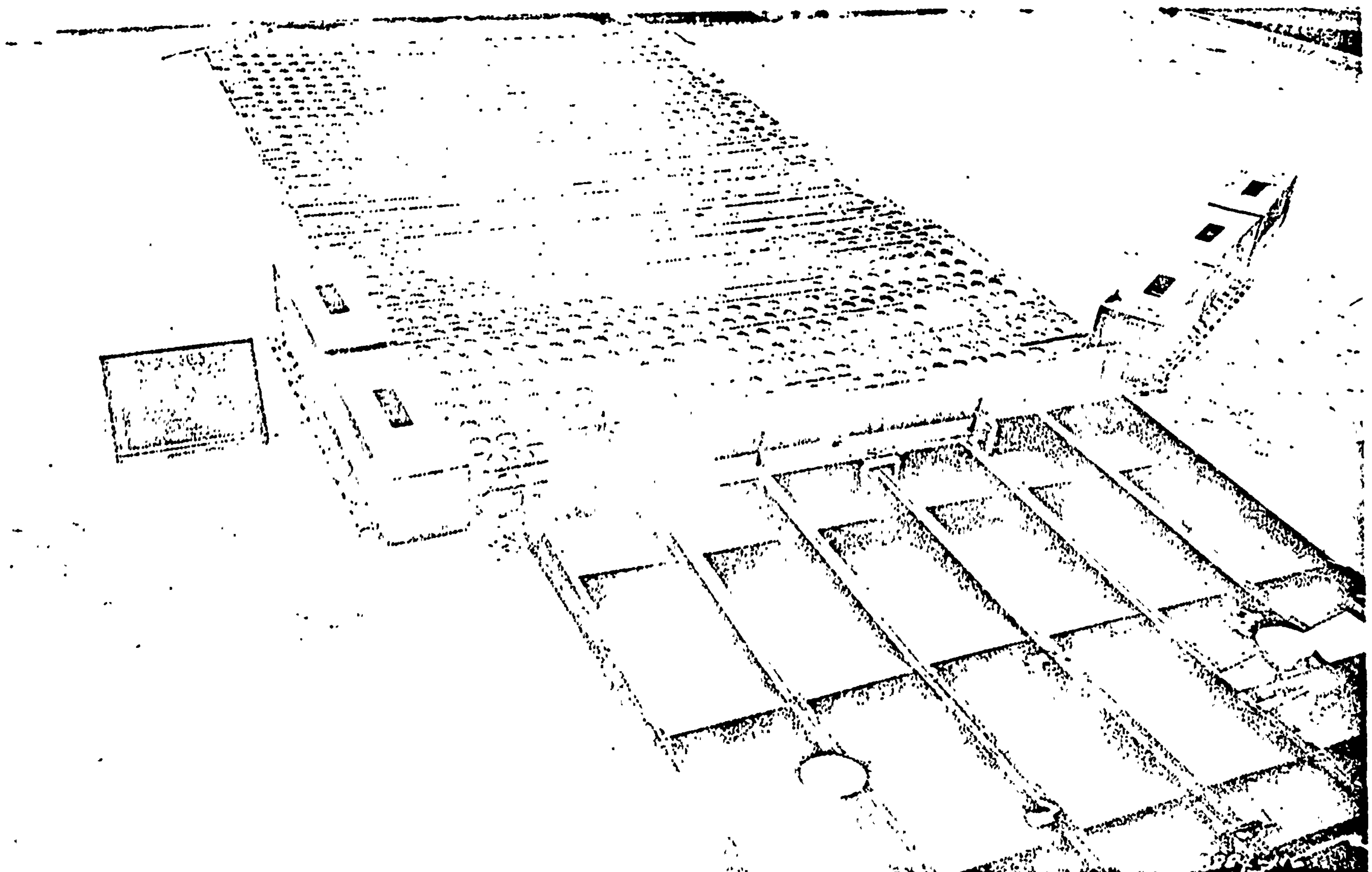
Photograph 22. Test run 4. Beach and M6 ramp after 3 hr of wave action



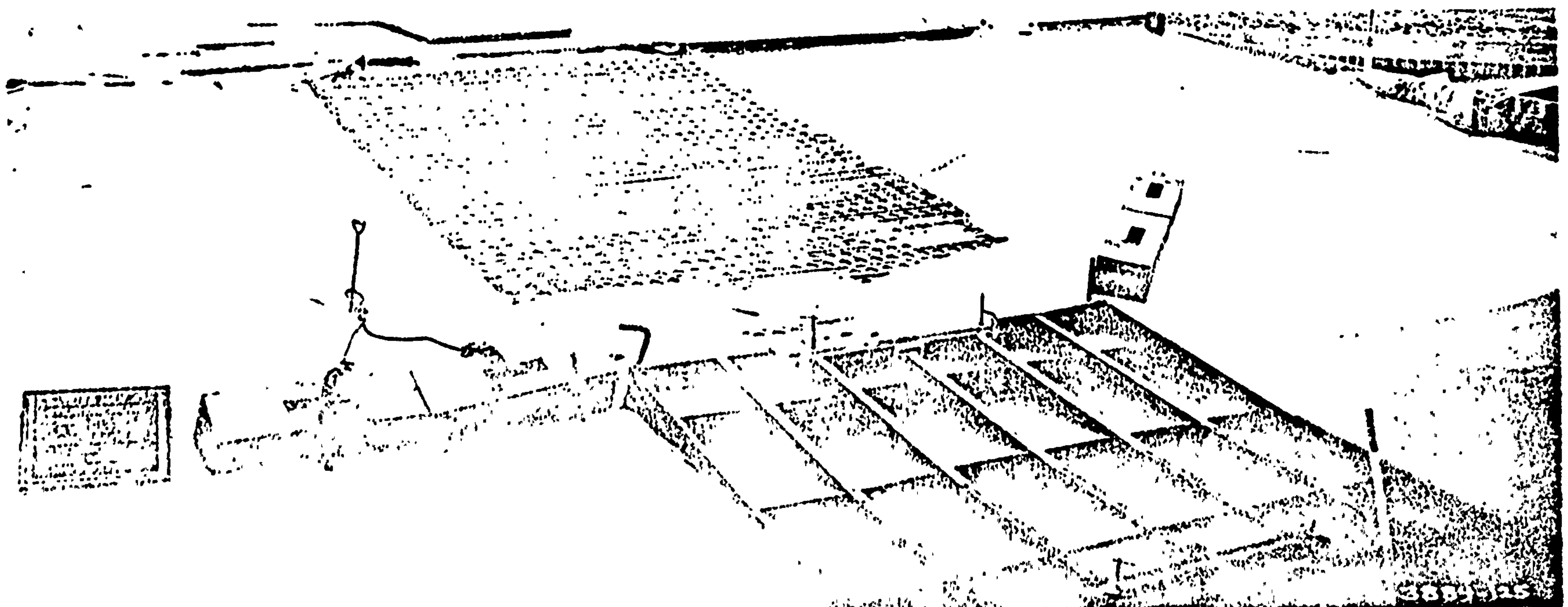
Photograph 23. Test run 4. Beach and M6 ramp after 15 hr of wave action



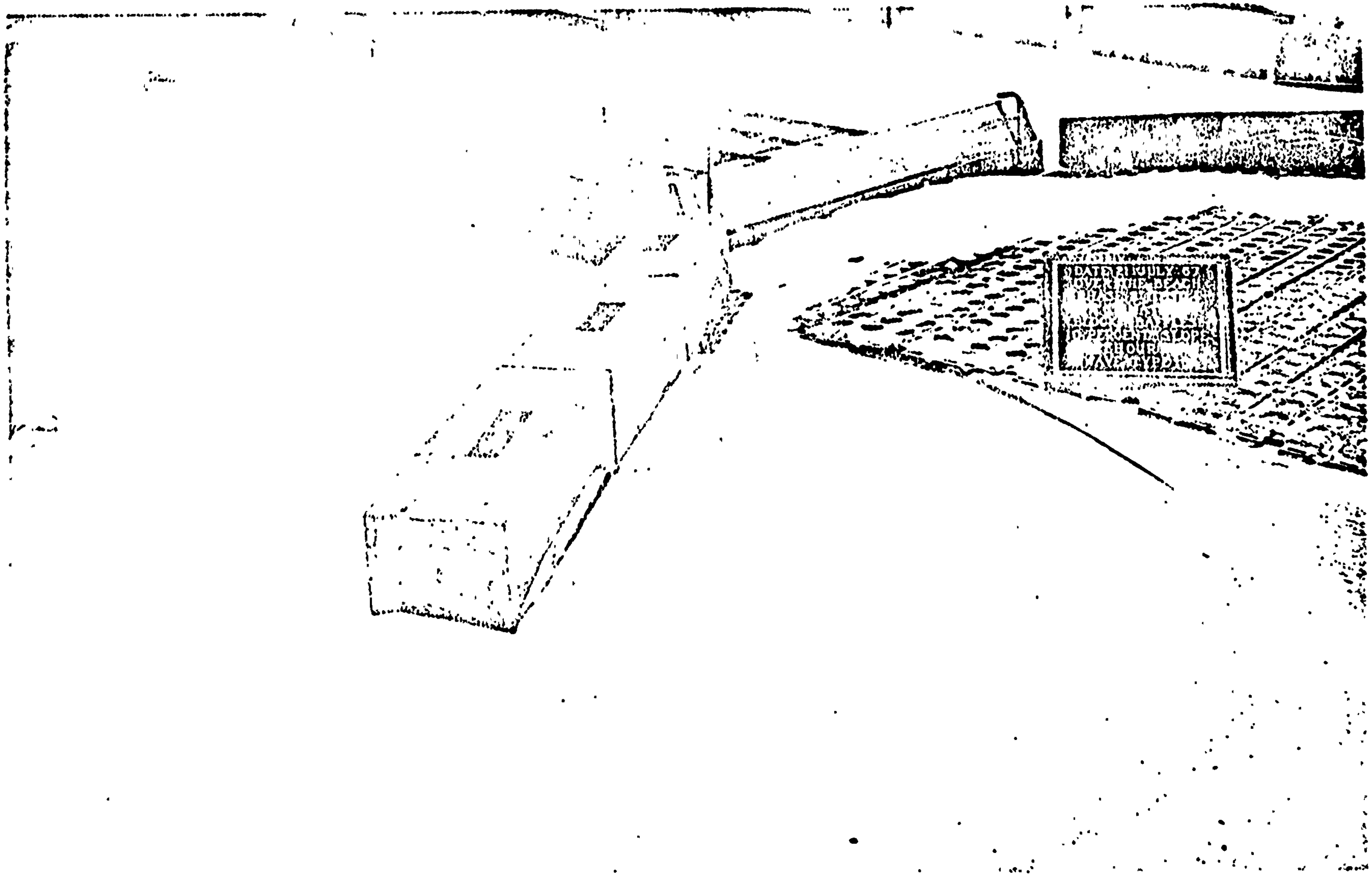
Photograph 24. Phase II. M6 ramp with 90- and 45-deg baffles; model barge in foreground



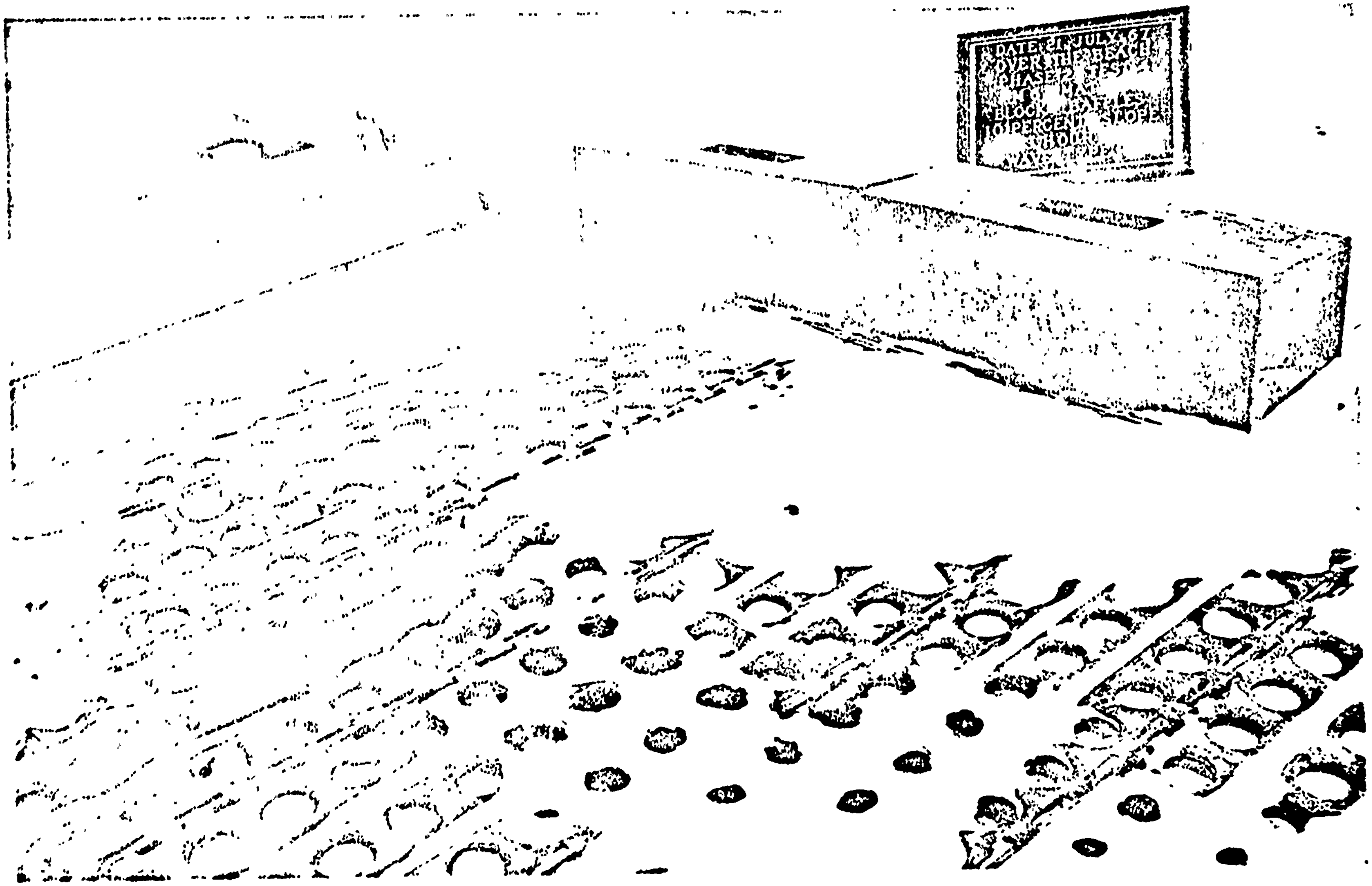
Photograph 25. Phase II. M6 ramp with parallel and 45-deg baffles, model barge sunk in foreground



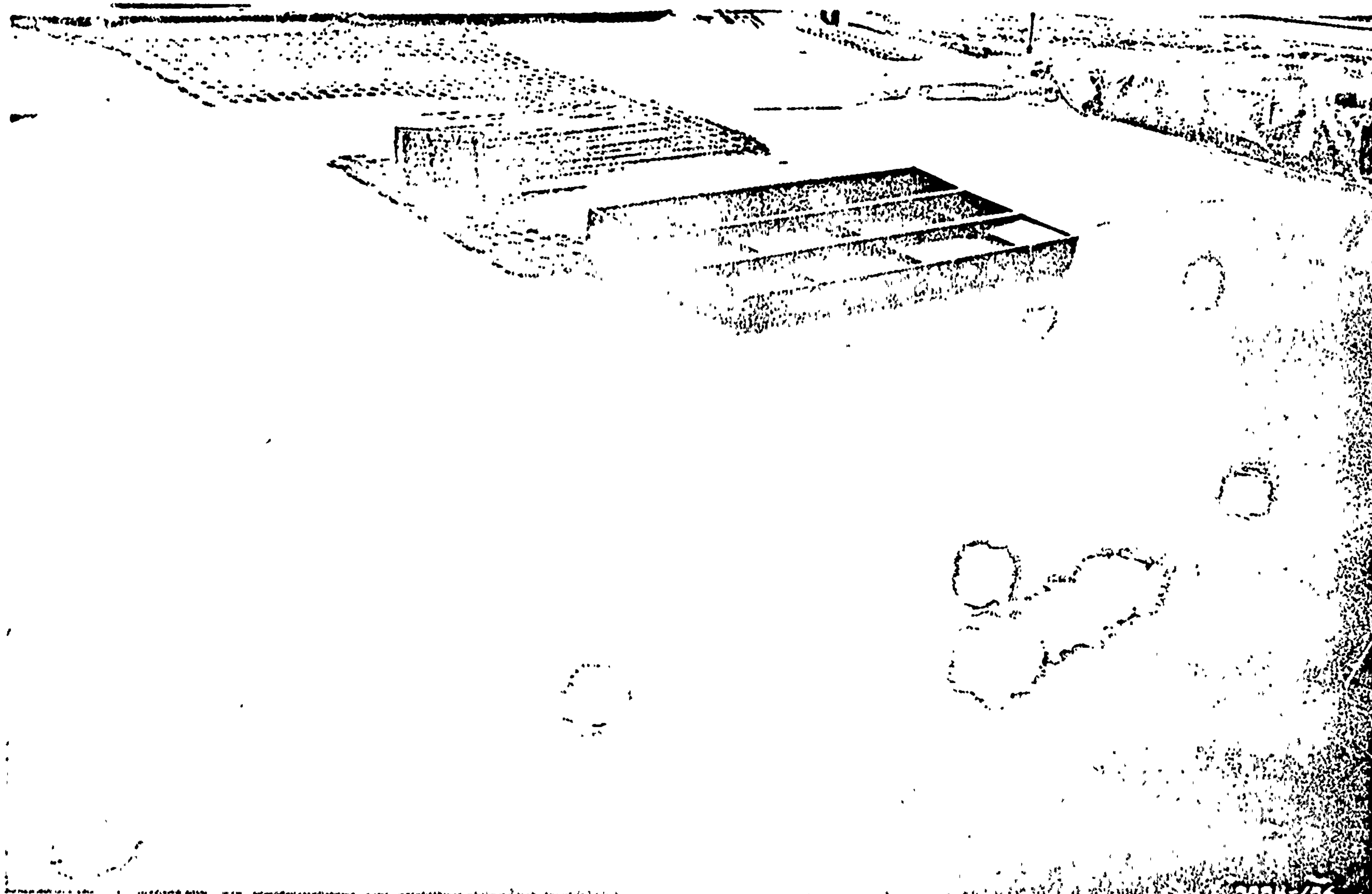
Photograph 26. Phase II. Movement of 90-deg baffle caused by 1 hr of wave action (left side of photograph)



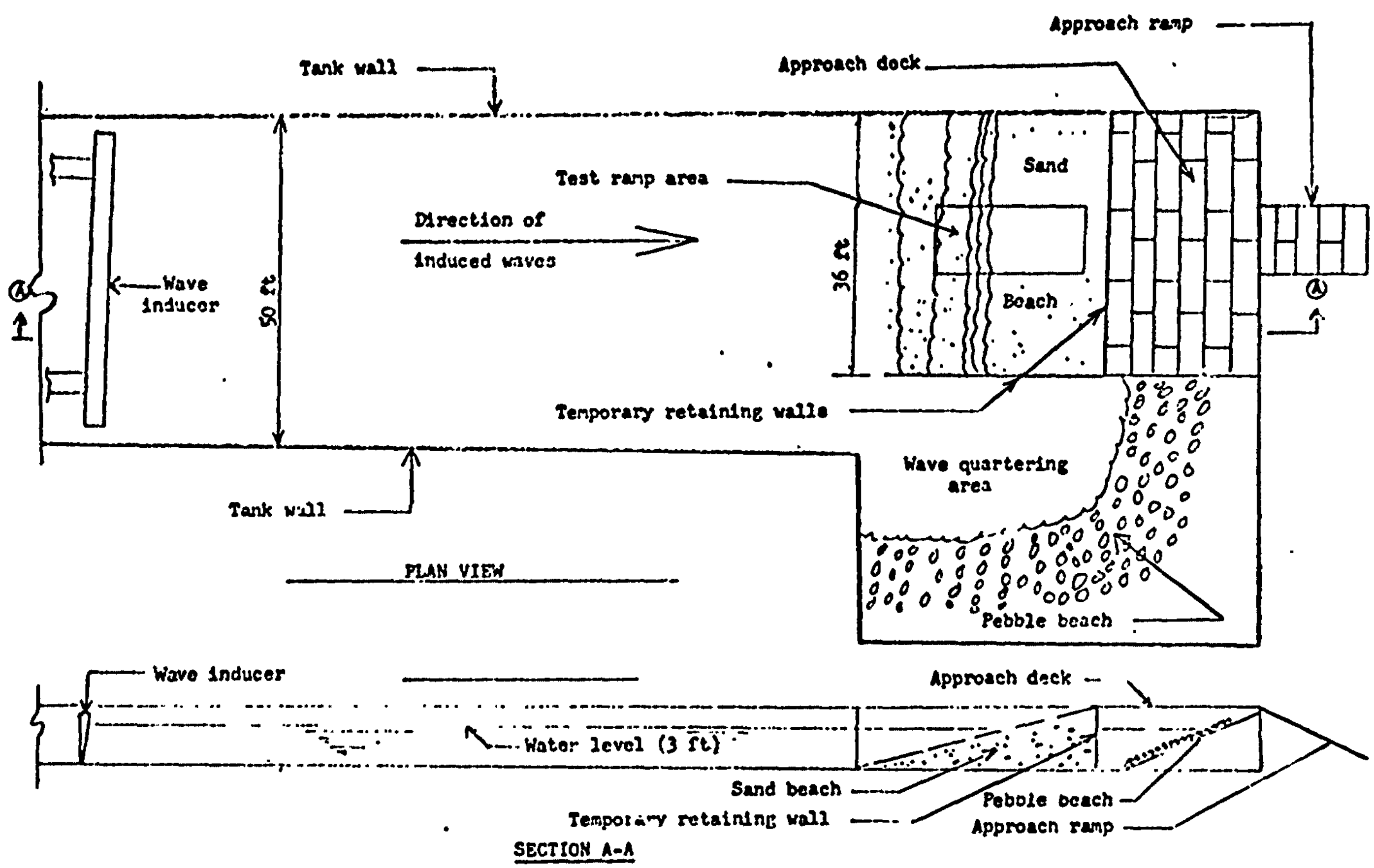
Photograph 27. Phase II. Erosion behind the 45-deg baffle after 1 hr of wave action



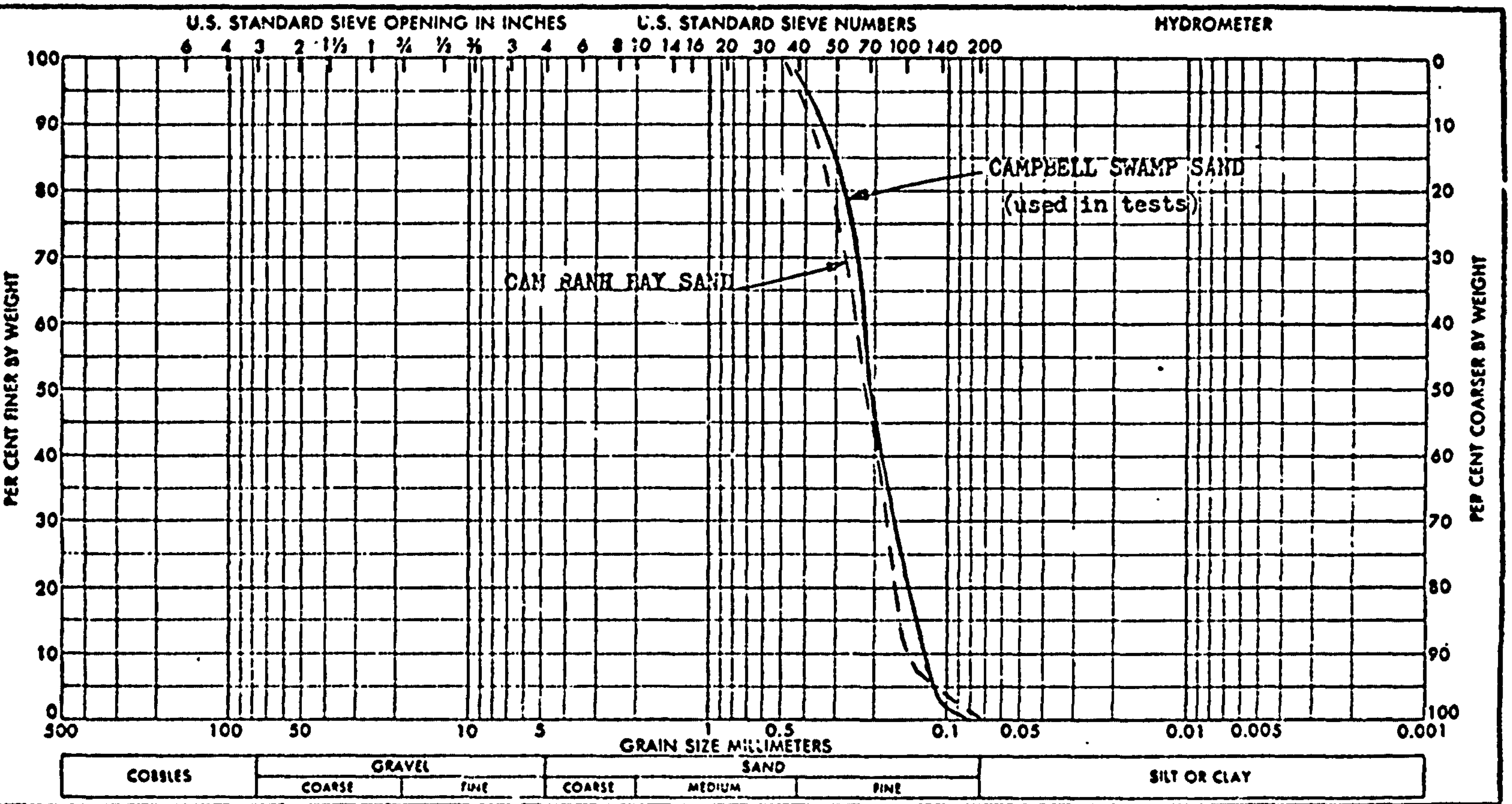
Photograph 28. Phase II. Parallel baffle and ramp after 3 hr of wave action



Photograph 29. Phase II. Condition of [illegible] without baffles after 3 hr of wave action



L-SHAPED WAVE TANK



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
Campbell Swamp	0-24 in.	Sand (SP) (Nonplastic)				
Cam Ranh Bay		Sand (SP) (Nonplastic)				

GRADATION CURVES

COMPARISON OF CLASSIFICATION DATA AND GRADATION CURVES

CAMPBELL SWAMP SAND AND CAM RANH BAY SAND

ENG FORM 2087
1 MAY 63

REPLACES WES FORM NO 1241, SEP 1962, WHICH IS OBSOLETE.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office, Chief of Engineers Washington, D. C.

13. ABSTRACT

Engineer tests were conducted on a full-scale model beach in a wave tank of the WES Hydraulics Division. The beach was constructed of sand approximating that found on beaches in the SE Asian theater of operations (TO). Beach slopes ranged from 10 to 20 percent. Waves induced upon the beach simulated those found in TO cove and bay areas. The tests were conducted by installing various types of expedient surfacing materials such as M8 pierced steel plank landing mat and XM19 aluminum landing mat with and without anchors and with and without T16 membrane over a prepared sand beach and subjecting these installations to wave action and vehicular traffic. The separate ramps were tested by first observing detrimental effects caused by wave action alone and then by a combination of wave action and traffic loading. These same factors were observed in determining detrimental effects of traffic and waves on a bare beach. Standard military vehicles used in the trafficking cycles were the M151 1/4-ton cargo truck and the M35 2-1/2-ton 6x6 cargo truck. None of the materials or combinations thereof satisfactorily stabilized the beach foreshore or provided an OTB ramp appreciably better than the natural, bare sand. Benefits gained by installation of any of these OTB ramps are short-term due to the rapid deterioration of the ramp foundation.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Beaches Hydraulic models Landing mats Membranes Sand Trafficability Vehicles Water waves						

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